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Jr Brannen

Nerita Smithæ. – Shell slightly produced; whorls flat, crossed by numerous rounded ribs. I found an imperfect specimen of this shell in Carboniferous Limestone at Corry, Arran, 5 June 1807. It bears a clear resemblance to the recent Nerita Peloria.

Hemings British Animals (1827) page 319.

p 132 r

CHAMBERS'S EDUCATIONAL COURSE—EDITED BY W. AND R. CHAMBERS.

RUDIMENTS OF GEOLOGY.

By DAVID PAGE.

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PREFACE.

GEOLOGY, in its aim to describe the materials composing the earth's crust, their mode of arrangement, and the causes which seem to have produced that arrangement, constitutes one of the most interesting and important of the natural sciences. Interesting, inasmuch as it exhibits the progressive conditions of the world from the remotest periods, and reveals the character of the plants and animals which have successively adorned and peopled its surface; and important, as it determines the position of those metals and minerals upon which the arts and manufactures so intimately depend. Valuable as are its deductions, Geology is comparatively of recent growth, it being only within the present century that accurate data have been collected, and those absurd speculations respecting the origin of the globe eschewed, which had so long impeded the legitimate prosecution of the subject. If, however, long repressed by the imprudence of its early cultivators, no branch of human knowledge has made more rapid progress since right modes of investigation were adopted—none attracted a greater degree of attention, or been more generally applicable to the economical purposes of life. To furnish an outline of the science in its present state of advancement, is the object of the following treatise, in which the leading facts are stated in as simple a manner as is consistent with accuracy. Technical terms, often so ignorantly inveighed against, have not been avoided, but have been gradually introduced with their explanations, to familiarise the learner with Geological language, and thus prepare him for the study of more advanced works, as well as for the practical prosecution of the subject. A uniform arrangement of the topics has been strictly adhered to, so as at once to assist the memory and facilitate reference; theoretical disquisitions have been studiously avoided; and a plain record of facts and observations presented, in order that the treatise might answer the end intended—namely, for Use in Schools and for Private Instruction.

EDINBURGH, *May* 1844.

Notabilia.

Most convenient small map (England) — & single sheet — & Gardner from Greenough's large Map — England &c — & Geolog. Society — London.

Interesting Treatise on & Consistency — Geology — Scripture &c — Newhaven (America) 1833 — Prof. Silliman as a supplement to an American edition, — Bakewell's Geology, 1833.

Some admirable articles on consistency — Genes. I. — & phenomena of Geology — N.Y. Observer, May, June, July, Aug. 1834

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De la Beche's Manual of Geology.
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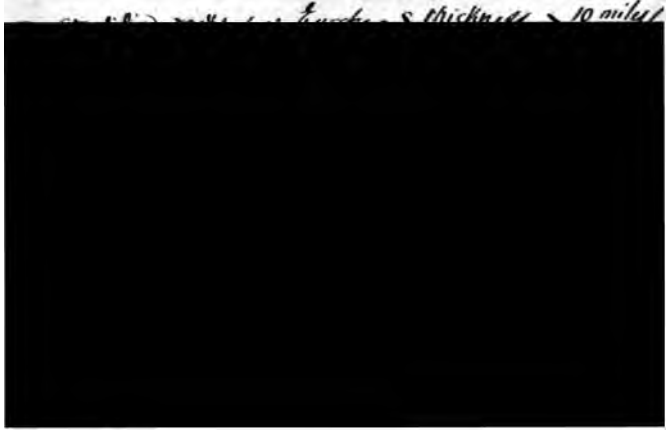


GEOLOGY.

OBJECTS OF GEOLOGY.

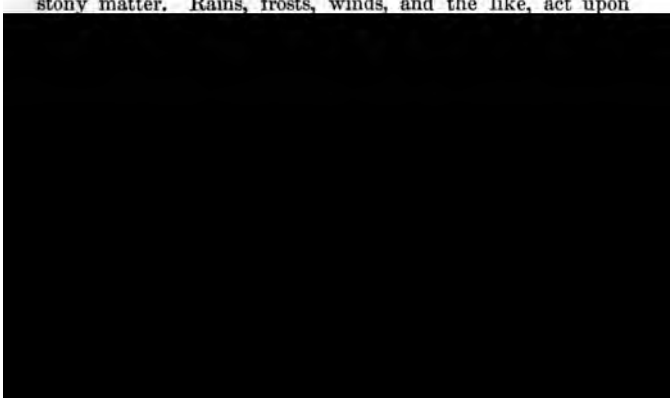
1. GEOLOGY is that science which treats of the materials composing the earth's crust, their mode of arrangement, and the causes which seem to have produced that arrangement.

2. *By the earth's crust* is meant that external shell or covering of solid matter which is accessible to man's investigation. The highest mountains do not rise five miles above the level of the sea, and the deepest mines descend only about a third part of a mile, so that, even were we perfectly acquainted with the entire space between the top of the highest mountain and the bottom of the deepest mine, it would form but a very insignificant fraction of the distance between the surface and centre of the globe, which is nearly 4000 miles. Thin as this crust may seem, it nevertheless presents innumerable objects for investigation; hence the magnitude of this science, which has been ranked, in point of importance, second only to that of astronomy.

3. *The materials which compose the crust of the globe* are exceedingly varied. For instance, one part of the surface is covered with sand, another with clay, and a third with gravel. How were these materials formed, whence were they derived, and by what agency were they laid down in their present position? Again, shells and bones may be found in the sand and clay, plants and trees in the peat-earth. How came these remains to be buried there, and are they similar to those animals and vegetables now living and growing upon the earth? As we dig through the sands, gravels, and clays, we come upon rocks, some in layers, others in masses;

some are hard and sparkling, others soft and earthy; and most of them differ in colour. Many of them differ also in the kind of matter of which they are composed, such as sandstone, limestone, coal, roofing-slate, &c. How were these rocks formed, and by what means were they laid down in their present positions? for rocks so different in kind as limestone, coal, and sandstone, must have been formed under different circumstances. Further, we find petrified shells, fishes, bones, and plants imbedded in these rocks; and different rocks contain different kinds of these remains. How were they imbedded there? Are they similar to shells, fishes, and plants now existing? Do they seem to have lived and grown in the sea, in fresh water, or on dry land? Such are a few of the questions which it is the province of the geologist to consider; and in doing so, he must ground his reasoning upon the analogy of the changes now going forward on the face of the globe, endeavouring to discover what relation they bear to former changes, and whether both may be ascribed to similar causes.

4. *The causes which modify the crust of the globe* are very numerous, differing in power, as well as in their mode of action. At present we find rivers bearing down mud, sand, and gravel, and depositing the same either along their banks, in lakes, or in the sea—these deposits forming layers of mud, sand, or gravel, which in some cases become consolidated, and assume a rocky appearance. If plants, shells, or dead animals be carried down at the same time by these rivers, they will be imbedded in the layers so formed, and will in course of time become petrified, or converted into stony matter. Rains, frosts, winds, and the like, act upon



those which mainly contribute to the modification of the crust of the globe. In general they act gently, and within limited spaces; occasionally with great violence, and over a large extent of country. These forces have always exerted themselves with greater or less intensity, and have always produced corresponding results. In reference to the masses of sand, gravel, and clay, now far removed from waters, and to the various rocks which are found at great depths in the earth's crust, it is the object of geology to discover whether they are to be ascribed to the operation of forces similar in kind, but greater in degree, than those above-described; and whether the plants and animals found petrified within them be or be not of the same kinds as those now existing. If they are of the same races, did they exist under similar circumstances? and if not, what seem to have been the conditions of the world under which they flourished?

6. *To solve the numerous problems which geology thus embraces*, a vast amount of research and knowledge is necessary. To account for the aggregation and positions of many rock masses, the geologist requires to be acquainted with the principles of mechanics; to treat of their composition and formation, the aid of chemistry must be called in; to describe and classify the remains of plants and animals, he must have recourse to botany and zoology; while, generally speaking, there are many of his problems, for the successful solution of which the assistance of almost every branch of natural science is necessary. An amount of acquirements so varied is beyond the compass of most minds; hence geology has been divided into several departments, which, while ultimately depending on each other for their progress, can be studied as individual sciences. These are—*Physical Geography*, which limits itself to the mere surface and configuration of the earth as occupied by land and water, mountains and valleys, and other external appearances; *Mineralogy*, which treats of the individual crystals or minerals of which rock masses are composed; and *Oryctology*, or *Palæontology*, which directs itself exclusively to the consideration of the fossil plants and animals that may be discovered in the crust of the globe.

7. *Abstract or speculative geology* comprehends all these branches, and, were it a perfect science, would present a history of the globe from its origin and formation, through all the changes it has undergone, up to the present time; describing its external appearance, its plants and animals, at each successive period. As yet, geology is the mere aim to arrive at such knowledge; and when we consider how

difficult it is to trace the history of a nation even over a few centuries, we cannot be surprised at the small progress geologists have made in tracing the history of the earth through the lapse of ages. To ascertain the history of a nation possessed of written records, is a task comparatively easy; but when these are wanting, we must examine the ruins of their cities and monuments, and judge of them as a people from the size and structure of their buildings, and from the remains of art found therein. This is often a difficult, and all but impracticable task; much more so is it to decipher the earth's history. It is true that certain geological facts are recorded; but the record is neither distinct nor of much antiquity. We learn that earthquakes have raised land above, or sunk it beneath, the sea; that volcanoes have formed mountains and buried cities, such as Herculaneum and Pompeii; that the mud of rivers has formed vast plains like the Deltas of the Nile and Ganges; that cities once on the sea-shore are now several miles inland; and that cities once removed from the sea have been washed away by its inroads, their sites now forming the bed of the ocean. Beyond a few facts like these, we have no written geological record; and, for the earlier history of the earth, must descend into the gravels, clays, and rocks which form its crust; judge of past changes by the character of these masses; and reason as to the kind of plants and animals which formerly peopled its surface, from the petrified remains which are entombed in the strata beneath.

8. *The practical utility of geology* is alike varied and extensive. The metals so indispensable to the purposes of civilised life are all dug in the shape of ores from the rocky crust, certain metals being found in certain rocks, and

turist in his endeavours to improve the fertility of the soil. Other practical advantages to be derived from the study of geology might be pointed out; but these will be best considered in a subsequent part of the treatise, when, as may be supposed, the student will be better able to judge of their importance.

EXPLANATORY NOTE.

GEOLOGY (Greek, *ge*, the earth, and *logos*, a discourse)—reasoning about the structure of the earth. The term *Geognosy* (from *ge*, and *gnosis*, knowledge) is sometimes used instead of geology, the former signifying absolute knowledge, and the latter implying speculative reasoning. Geology, however, is the term most frequently in use, and is likely to continue so.

CRUST—the outer or solid covering of any body, such as the crust of a loaf, the shell of an egg, &c. The crust generally differs in quality from the internal parts, which it covers; hence the term "crust of the earth" is used to distinguish it from the interior of the globe, concerning which we have no certain knowledge.

PETRIFIED, PETRIFACTIONS (Latin, *petra*, a stone, and *facere*, to make)—to make or change into stone. When a shell, bone, or piece of plant, by being enclosed in rocky matter, becomes hard and heavy like stone, yet retains its shape, it is said to be petrified. Petrification is thus caused by the particles of stony matter entering into, and filling the pores of the animal or vegetable structure; lime-water, for instance, entering into the pores, and between the fibres of a piece of wood, makes it a limy petrifaction.

FOSSIL (Lat., *fossus*, dug up)—anything dug up out of the earth is fossil; but the term "fossils," or "fossil remains," is now generally applied to petrified vegetable or animal remains dug out of the earth's crust.

ORYCTOLOGY (Gr., *orusso*, to dig, and *logos*, a discourse)—a discourse or reasoning about things dug up. PALÆONTOLOGY (from *palaios*, ancient, *onta*, beings, *logos*, a discourse)—a discourse or reasoning about ancient beings. Both of these terms are used by geologists to signify the science of fossil remains; some objecting to oryctology as merely referring to things *dug up*, while common stones are dug up as well as remains of plants and animals; others objecting to palæontology, because, though it refers to *ancient beings*, it does not imply that they are fossil.

STRATUM, plural STRATA (Lat., *stratus*, strewn, or spread out). When different rocks lie in succession upon each other, each individual forms a *stratum;* and is so termed from its appearing to have been laid, or spread out in order. Rocks arranged in parallel layers are thus said to be *stratified;* and those among which there is no appearance of this parallel arrangement, *unstratified.*

GENERAL STRUCTURE AND CONDITIONS OF THE GLOBE.

9. Before entering upon the consideration of the materials which compose the external crust, there are certain facts concerning the general structure and conditions of the globe itself, a knowledge of which is necessary to the prosecution of geological research. These are its Figure, Density, Temperature, and Surface Configuration; the Distribution of Land and Water, Constitution of the Sea, the Atmosphere, and Planetary Relations.

FIGURE.

10. THE FIGURE OF THE EARTH is nearly that of a sphere or globe. A diameter (measure through) from north to south is said to be polar; one from east to west, equatorial. If the earth were perfectly spherical, these diameters should be of the same measure; but it has been found by accurate investigation that the polar is less than the equatorial by about 26½ miles. According to Herschel—

The Equatorial is . .	7925·648 miles.
The Polar is . .	7899·170 miles.
Difference, . .	26·478 miles.

This gives a flattening or compression at each pole of about 13¼ miles; so that the figure of the earth is, strictly speaking, that of an *oblate spheroid*.

DENSITY.

13. THE DENSITY OF THE EARTH has also been computed with considerable accuracy. By weighing the most prevalent rocks, it has been found that the solid crust composed of them is about two and a-half times heavier than water; but from experiments made on the attraction of mountains of known bulk, compared with the attraction and bulk of the globe, it has been inferred that the density of the whole mass is five times that of water. In other words, the earth, as at present constituted, is *five times* heavier than a globe of water of similar dimensions, and *twice* that of the rocks at its surface.

14. *The interior or central material* of the earth being thus necessarily heavier than the rocks which form its crust, numerous speculations have been indulged in as to what the nature of these materials may be. It has been said that air, water, or stone, as known at the surface, cannot compose the interior parts; for if the law of gravitation exert itself uniformly towards the centre, either of these would be so compressed as to give the earth's mass a mean density greater than the laws of attraction will allow. Water, for instance, would, at the depth of 362 miles, be as heavy as quicksilver, and air as heavy as water at 34 miles; while at the centre, the density of marble would be increased 119 times! To make their suppositions accord with the mean density of the earth, that is, to reconcile the forces of gravitation and attraction, theorists have successively proposed gaseous fluids, heated matter, and even light itself, as the central material.

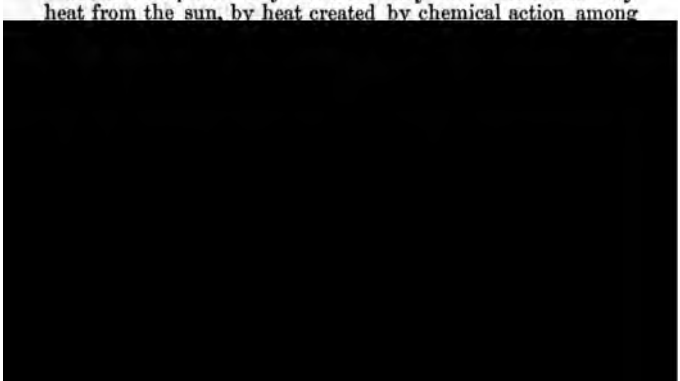
15. Laying aside all hypotheses, our knowledge respecting the density and internal structure of the earth may be thus summarily stated:—1. The density of the rocky crust is, on an average, two and a-half times that of water; 2. The mean density of the whole mass is five times that of water; 3. The central parts cannot be composed of similar material with the crust, otherwise their compression would become so great towards the centre, that the mean density of the earth would be much greater than it is; and, 4. That the condensation of the central masses must be counteracted by some expansive influence, such as heat, or have a constitution unlike any substance with which we are acquainted at the surface.

TEMPERATURE.

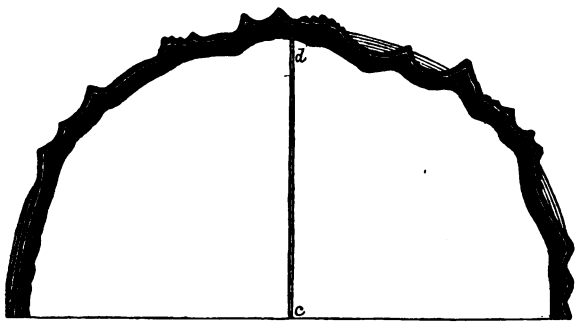
16. THE TEMPERATURE OF THE EARTH is a subject the consideration of which exercises a most important influence on the reasonings of geologists. There is, first, the *surface temperature*, which affects the growth and distribution of plants and animals; second, the *temperature of the crust*, which may give rise to gaseous exhalations, thermal springs, mineral and metallic transformations; and, third, there appears to be an internal or *central temperature*, having its seat beneath the solid crust, and which seems to be the cause of volcanoes, earthquakes, and other similar phenomena.

17. *Of the surface temperature*, we know that it is influenced, first, from day to day, and from season to season, by the heat of the sun; second, by the degree of latitude, being warmest at the equator, and gradually diminishing towards either pole; third, by the distribution of land and water, the sea being less liable to sudden fluctuations of temperature than the land; fourth, by the nature of the surface, the kind and colour of matter variously absorbing and retaining the heat derived from the sun; and lastly, by the elevation of the land above the mean level of the sea, the more elevated being the colder regions. All these influences are at present in active force, affecting more or less the growth and distribution of animal and vegetable life; and in like manner must they have exerted themselves at former periods, though perhaps increased or counteracted by certain conditions not now existing.

18. *The temperature of the crust* may be affected either by heat from the sun, by heat created by chemical action among



nually kept within a given limit. By actual experiment, it has been ascertained that, at a given depth beneath the surface of the earth, there is a point at which the temperature remains constantly the same, being uninfluenced by any causes which affect the surface. This depth will vary according to the kind of material of which the crust at any given place is composed, be these materials rocks, sand, or water; but in no instance has it been found to be less than 60, or more than 100 feet. A series of these depths, as represented by the white line in the subjoined diagram, is called by geologists *the stratum of invariable temperature.*



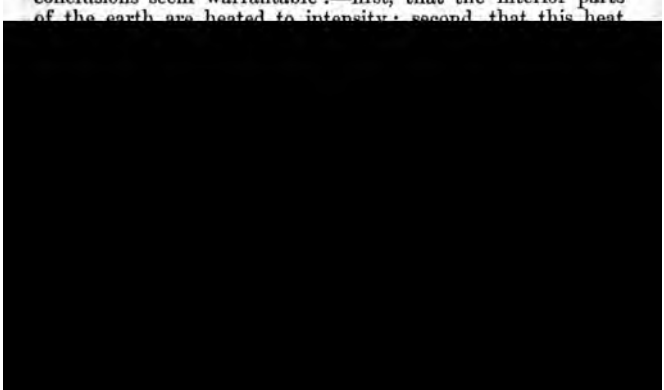
Section, showing the stratum of invariable temperature, and relative thickness of the solid crust.

20. *Proceeding beyond this invariable stratum,* towards the centre (*c*), it has been found that the temperature gradually increases; a circumstance which attracted the attention of philosophers more than a century ago. In 1802 D'Aubuisson revived the investigation, and since that time, observations have been made in the principal mines of Europe and America. The greatest depths at which experiments have been conducted, are 1713 feet in Mexico, 1584 in England, and about 1300 in Germany; and in all of these the temperature has been found to increase according to the depth. In 1827 M. Cordier published a memoir on this interesting subject, in which he collected the observations of others together with his own; and having made allowance for the heat arising from the breathing of miners, for the combustion of lamps, and communication with the atmosphere, he drew the following general conclusions:—1. Below the invariable stratum, the temperature at any given depth remains perfectly

constant for several years; 2. That below the invariable stratum the temperature goes on increasing with the depth; and, 3. That, taking the average of observations, this increase of temperature goes on at the rate of one degree of Fahrenheit's thermometer for every 45 feet. Others have allowed 60 feet for the rise of one degree; but even taking this lower estimate, it must follow, if the increase go on in the same ratio, that a temperature equal to 100 degrees of Wedgewood's pyrometer would be found at the depth of 160 miles. But, 100 degrees of Wedgewood is sufficient to keep in fusion any of the known rocks, so that, according to this estimate, the solid crust of the earth cannot be more than 60 or 80 miles in thickness—a mere fractional film of the distance from the surface to the centre.

21. *Of the internal or central heat* of the globe, we know nothing by actual experiment; but are left to infer as to its amount from the descending increase of temperature observable in the solid crust, and from the occurrence of hot-springs, vapour fissures, and volcanoes. That the heat of the crust increases as we descend, has been fully established by experiments in mines, in Artesian wells, and in the waters of other deep-seated springs; and if this temperature goes on increasing at the ratio above-mentioned, then the interior parts must be heated to an enormous degree; so much so, indeed, as fully to counteract that law of compression formerly adverted to, and which would render all known matter, if placed at the centre, so dense as to be inconsistent with the mean density of the globe.

22. *Taking all circumstances into account*, the following conclusions seem warrantable:—first, that the interior parts of the earth are heated to intensity; second, that this heat



taken as the standard or measure; hence, if water be assumed as weighing 1, the rocky materials composing the earth's crust will be 2½, or two and a-half times heavier than water.

ARTESIAN WELLS (*Artois*, a district in France)—a term applied to wells sunk by digging or boring perpendicularly through various strata, from the circumstance that this mode was first practised in the district above referred to.

THERMAL (Greek, *therme*, heat)—warm or hot. Thermal and igneous are sometimes used indiscriminately; but it is more accurate to make a distinction. Thus, in treating of volcanoes, we speak of *igneous* agency; in treating of hot-springs, *thermal* is the more appropriate term.

TEMPERATURE OF THE EARTH.—The chief of those who have conducted experiments relative to this subject are Gensanne, Saussure, D'Aubuisson, Fourier, Cordier, Quetelet, and Arago, in France, Germany, &c.; Sir John Leslie, Fox, Forbes, &c. in Britain; and Humboldt, in Mexico. Their experiments present a wonderful degree of coincidence, and are chiefly of three classes:—1. Those made in mineral veins, or in mountain masses, such as granite; 2. Those made in stratified rocks, as in coal mines; and, 3. Those made in Artesian wells and other deep-seated springs.

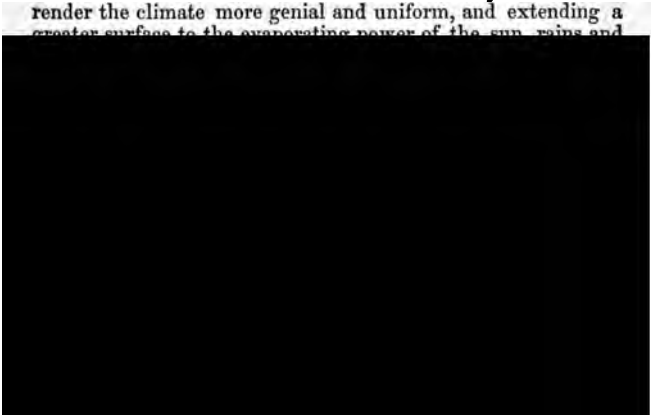
SURFACE CONFIGURATION.

23. THE SURFACE CONFIGURATION OF THE EARTH is more the study of physical geography than of geology proper; but it is necessary to observe in what manner it influences the geological changes now in progress. The surface of the earth is extremely irregular, being diversified by hills and valleys, rivers, lakes, seas, &c. Portions of it are covered with woods and forests; other portions are elevated above the limits of vegetable or animal life, and covered with eternal snows. Some parts of the exposed surface are so hard, that no sensible decay is experienced for ages; others so soft and loose, that scarcely a shower falls without carrying away a portion to some lower level. These differences of surface material are also influenced by steepness and irregularity of position; the transporting power of streams and rivers being proportioned to the rapidity of their descent. These are familiar instances of the numerous changes effected by diversity of surface configuration; but the student has only to cast his eye over his own district, to be convinced how many geological results depend upon this cause. Those immense plains —the steppes of Northern Asia, the prairies of North and the pampas of South America—must affect and be affected in a different manner from the Himmaleh, Alps, Andes, and other mountain ranges. The showers and snows which produce torrents and avalanches on the Alps, form merely springs and harmless streams on the Apennines; and while the sluggish river is forming inland plains with its mud, the rapid torrent is carrying its burden forward to the bottom of the ocean.

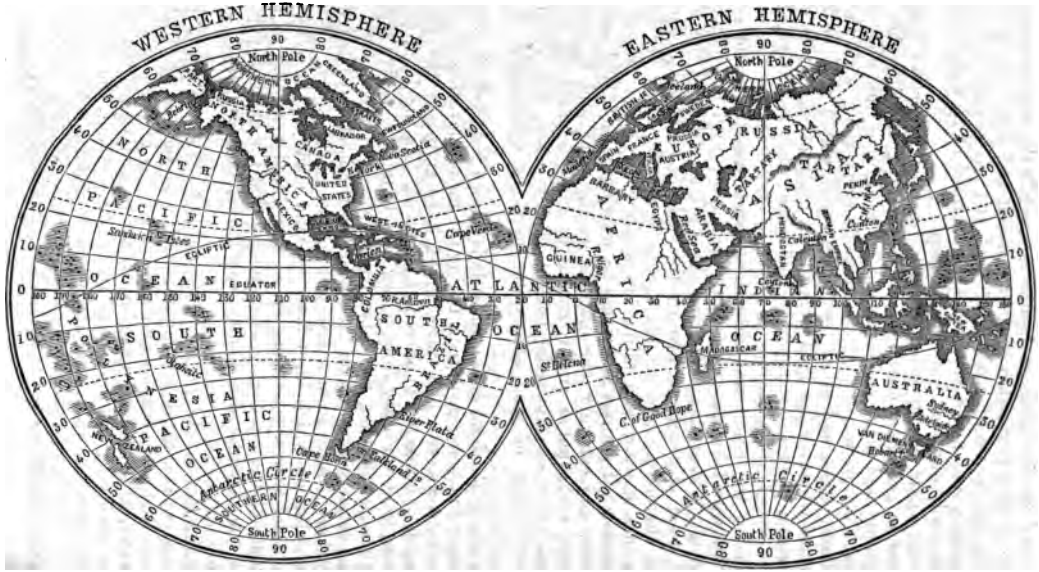
24. *The surface outline of the earth* is so irregular that even physical geography, with all the facilities afforded by modern intercourse, has yet presented us with a very general description; and before we can estimate the full force of this configuration as a geological agent, we must know more of the relative elevations and depressions of the land, and the nature of the rocky substances so elevated and depressed. Of the surface configuration of the world in its earlier ages, we have no positive knowledge; but we are certain that whatever it might be, it would materially influence the changes then going forward, just as the same cause is operating at the present moment.

DISTRIBUTION OF LAND AND WATER.

25. THE DISTRIBUTION OF LAND AND WATER, upon which so many geological phenomena depend, is influenced by this principle alone; namely, that so long as the same quantity of water remains on the globe, a fixed amount of space will be required to contain it. If the difference between the elevations and depressions of the solid crust be small—in other words, if the hollows in which lakes and seas are spread out be shallow—their waters must extend over a greater space; and if these hollows be deep, the waters will occupy less extensive areas. The operation of this principle the student should bear in mind; for if, in the earlier ages of the world, the elevation of the land was less general, the waters would occupy larger spaces, and this more extended area of shallow water would act in various ways. It would render the climate more genial and uniform, and extending a greater surface to the evaporating power of the sun, rains and



MAP OF THE WORLD.



placed in the northern hemisphere, while the waters occupy the greater proportion of the equatorial and southern regions. The relative configuration of land and sea is extremely irregular, and no conception can be formed of it, unless from the study of a well-constructed map.

27. *This configuration exercises a most important influence* in geological operations by determining the direction of oceanic and tidal currents, and by modifying the direction and force of waves. Ocean-currents carry along with them plants, trees, and other floating material, which will be arrested wherever the land presents an obstruction. Tides exercise a powerful transporting influence: they rise to greater or less heights, according as they are obstructed by the outline of the land; and while they sweep headlands and promontories bare, they lay down sand and gravel in sheltered bays. Waves also wear away the land, according as the line of coast obstructs or favours the violence of their progress. If, therefore, these oceanic agents be wearing away dry land in one quarter, and filling up shallow bays and creeks in another; if springs and rivers be wearing down inland countries, and carrying the material to the sea; and if, moreover, earthquakes and volcanoes be here submerging land, and there elevating the bottom of the ocean, the relative distribution of land and water must be continually fluctuating.

28. *Of the depth of the sea* little is known from actual soundings; but some geologists, taking the mean elevation of land at between two and three miles, have supposed the mean depth of ocean not to exceed that extent. As the land, how-

CONSTITUTION OF THE OCEAN.

30. OF THE CONSTITUTION OF THE OCEAN chemical research affords us pretty accurate data. Water, whether fresh or salt, may contain impurities—such as clay, sand, gravel, animal and vegetable matter; but if left at rest, these by their own weight soon fall to the bottom. Such substances are said to be *mechanically* suspended; and, when deposited at the bottom, they form *sediment*. Besides impurities of this description, water may contain matter which will not fall down, and which is said to be held in *chemical solution*. Sea water of the Atlantic, according to Dr Marcet, contains 4 3-10th grains of saline matter in every hundred; while, according to Dr Murray, the water of the German Ocean contains only 3 3-100th grains. This saline matter consists chiefly of muriate of soda (common salt), sulphate of soda, muriate of lime, and muriate of magnesia. It has been also ascertained that the southern ocean contains more salt than the northern; that small inland seas, though communicating with the ocean, are less salt than the ocean; that the Mediterranean contains a greater proportion of saline matter than the Atlantic; and though the saltness of the sea be pretty uniform at great depths, still, at the surface, owing to the admixture of rain, river, and iceberg water, it is not quite so salt.

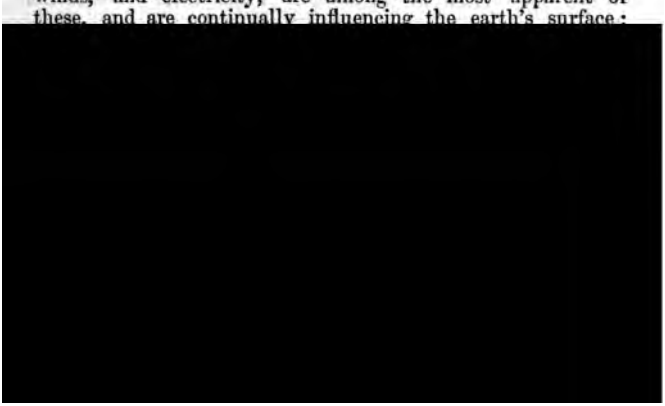
31. *A knowledge of the constitution of the ocean* is necessary to the explanation of numerous facts in geology. The saline constituents must influence more or less all chemical changes, rock deposits, and animal and vegetable life, which take place in the ocean. From these constituents shell-fish and coral animals derive the matter of which shell-beds and coral-reefs are constructed; and by this same constitution, marine animals and plants are made to assume a character which distinguishes them from the inhabitants of fresh waters.

32. *The pressure of the sea* (which depends on its depth) also exerts an important influence, as what takes place near the surface would be impossible at greater depths. There, animal and vegetable life, as known to us, cannot exist; sand and mud, which remain loose near the shore, would become much consolidated if subjected to this pressure; and, according to the experiments of Sir James Hall, even limestone could be fused without the loss of its carbonic acid. Other results, depending upon the present constitution of the ocean, might be pointed out; but enough, we trust, has been stated to impress the student with a conviction of its geological importance.

THE ATMOSPHERE.

33. THE ATMOSPHERE, which everywhere surrounds the globe, is either of itself the immediate cause of numerous terrestrial changes, or it is the medium through which they are effected. The air is a gaseous fluid, produced by the combination of 79 parts of nitrogen with 21 of oxygen, every 100 such parts containing a small portion of carbonic acid and other extraneous impurities. It is indispensable to the life of plants and animals, and an alteration of its constitution would completely change the relations of animated nature; for, while a greater proportion of carbonic acid would be highly favourable to vegetation, it would be utterly destructive to animals. The proportion of nitrogen and oxygen in the atmosphere is at present nearly as 4 to 1; change this, and 5 of oxygen with 1 of nitrogen forms a compound (nitric acid, or aquafortis) so corrosive, that even the metals are dissolved by it. The air is an elastic or compressible medium; and, consequently, the lower strata near the earth will be compressed by the weight of those above them, and thus the air will become rarer as we ascend. From measuring the rate at which this rarity takes place, it has been calculated that at the height of forty-five miles the atmosphere would become so rare as to be inappreciable. Forty-five miles has, therefore, been assumed as the limit of the atmosphere.

34. *This aërial medium is the laboratory in which numerous operations are effected.* Vapours, rains, snows, clouds, winds, and electricity, are among the most apparent of these, and are continually influencing the earth's surface;



influence on the changes which have been effected, or are now going forward, on its surface. From the sun it derives light and heat, those agencies so indispensable to animal and vegetable existence; on its relation to the sun and moon depend those important tidal influences already adverted to; while to the same relation it owes its daily and annual revolutions, with all their attendant results. A permanent increase or diminution of the sun's heat would change the whole vegetable and animal economy; the approach of a comet might derange the present order of the globe's rotations; and a slight shifting of the earth's axis, so as to displace the present planetary positions of its poles and equator, would so alter the distribution of plants and animals, would so derange its surface configuration, and change the distribution of land and sea, that the face of nature would then present an entirely different picture. So far as history or the calculations of astronomy over a space of 3000 years will permit us to infer, no such revolutions have taken place; nor do the tides, the sun's heat or light, seem to have been in the least affected. But while this is true, it does not prevent the possibility of such changes; and certain geological appearances present themselves in the earth's crust, which cannot be accounted for unless by the supposition of such revolutions.

36. *The daily and annual rotations of the earth,* the sun's light and heat, the ebb and flow of the tides, &c. are *permanent* occurrences, dependent on the planetary relations of the globe; catastrophes, such as would arise from the contact of a comet, a change in the position of the earth's axis, or the like, would be *temporary* and *peculiar.*

EXPLANATORY NOTE.

ELEVATIONS AND DEPRESSIONS.—These are terms applied to the risings and fallings of the surface of the earth—from the slightest undulation to the highest mountain, and from the gentlest hollow to the greatest depth of ocean. The greatest heights with which we are acquainted are those of the Himmaleh range in Asia, the Dhawalagiri Peak being 28,077 feet, and the Jewahir 25,747. The Andes, in South America, are the next in order, the Nevado di Sorato being 25,250 feet, and Illimani 24,450. In Europe, the Alps rise (in Mont Blanc) to 15,668 feet, the Pyrenees to 11,283; and in Africa, Geesh, in Abyssinia, is 15,000, and the Peak of Teyde (Teneriffe) gives 12,180. As some parts of the dry land are above the level of the sea, so also some portions are beneath—such as the central regions of Asia around the Caspian and the Aral seas, where the surface has been ascertained to be from 80 to 100 feet actually lower than the level of the ocean. But the greatest depressions in the solid crust are those occupied by the sea, where actual soundings have reached depths of nearly a thousand

fathoms; and to which other calculations have assigned a depth of no less than nine miles.

AVALANCHES (French, *lavanches, avalanges*)—are accumulations of snow, or of snow and ice, which descend from lofty mountains, like the Alps, into the valleys beneath. They originate in the higher regions of mountains, and begin to descend when the gravity of the mass becomes too great for the slope on which it rests, or when fresh weather destroys its adherence to the surface. Avalanches are generally distinguished as *drift, rolling, sliding*, and *glacier* or *ice* avalanches. Drift are those caused by the action of the wind on the snow while loose and powdery; rolling, when a detached piece of snow begins to roll down the steep—it licks up the snow over which it passes, and thus acquires bulk and force as it descends; sliding, when the mass looses its adherence to the surface, and descends, carrying everything before it which is unable to resist its pressure; and glacier or ice, when pieces of frozen snow and ice are loosened by the heat of summer, and precipitated into the plains below.

ICEBERG (German *eis*, ice, and *berg*, mountain)—the name given to the masses of ice resembling mountains, often found floating in the polar seas. They are sometimes formed in the sea itself by the accumulation of ice and snow; at other times they seem to be glaciers which have been piling up on a precipitous shore, till broken off and launched into the ocean by their own weight. Masses of this kind have been found in Baffin's Bay two miles long and half a mile in breadth, rising from 40 to 200 feet above the water, and loaded with beds of earth, gravel, and rocks. Some idea of the size of these icebergs may be formed from the fact, that the mass of ice below the level of the water is about eight times greater than that above. As they float towards warmer regions, they gradually dissolve, dropping their burden of rock debris, and thus strewing the bottom of the ocean with clay, gravel, and boulder stones, some of which are many tons in weight.

PROPORTION OF LAND AND SEA.—The proportion of land to sea is, accurately, as 266 to 734. If, therefore, the whole superficies of the globe be taken at 196,816,658 square miles, it follows that the dry land occupies 52,353,231 square miles, and the ocean an area of 144,463,427

CAUSES MODIFYING THE STRUCTURE AND CONDITIONS OF THE GLOBE.

37. Had the general structure and conditions of the globe, as described in the foregoing section, been subjected to no modifying causes, they would have remained unchanged from the beginning of time, and the earth would have presented now the same appearance as at any former period. But these very conditions are themselves the causes of change, for they mutually act upon each other, and give rise to innumerable agents which have continued through all time to modify the face of nature. Thus, for example, the planetary relations of the earth enable it to derive heat from the sun; this heat vaporises the water of the ocean, the vapour produces rains, these rains form springs and rivers, the rivers wear down the land, and thus change the surface configuration; the matter borne down by the rivers forms new land along the sea-shore, altering the distribution of land and water; and this distribution of land and water materially affects the kind and distribution of plants and animals. This is a simple instance of the changes produced by the action and reaction which takes place among the general conditions of the globe; and the student would do well, at this stage of his progress, to familiarise himself with such trains of cause and effect, as it is only by the ready application of similar reasoning that he will be able to comprehend many of the phenomena hereafter described.

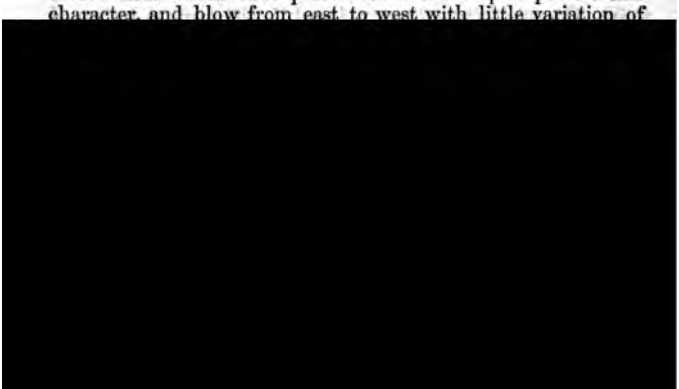
38. *The modifying causes* produced by the mutual influence of the general conditions already considered are exceedingly numerous and varied. At present, it is necessary to notice only such as seem to account for the principal facts connected with the solid materials which form the crust of the globe, and the order and manner of their arrangement. These causes, or agents, may be divided into four great classes; namely, ATMOSPHERIC, AQUEOUS, IGNEOUS, and ORGANIC; and their modes of action may be either *mechanical*, *chemical*, *electrical*, or *vital*.

ATMOSPHERIC AGENCIES.

39. ATMOSPHERIC AGENTS act either mechanically or chemically: the action of wind in drifting loose sand is mechanical, the action of the air in *weathering* the surface of rocks is chemical. The atmosphere may either act directly, as in

the case of winds, or indirectly, as in the production of waves, the effects of which on the sea-coast are often destructive and extensive. The changes produced on the earth's crust by atmospheric agency are sometimes slow and gradual, such as in the crumbling down of rocks; or immediate, as in the uprooting of forests by tempests, and the covering of green valleys by barren sand-drift. The air, or atmosphere, is one of the most important elements, and is more or less connected with every operation in nature. By it the sun's light and heat are equally diffused; it is indispensable to the existence of plants and animals; and it is the great laboratory in which the waters of the ocean are purified and distributed over the face of the globe. These may be said to be universal functions of the atmosphere. It also acts peculiarly, and over limited extent, as in the production of winds, frost, heat, electricity, and gaseous admixtures.

40. *Winds* are aërial currents. When the air of one region becomes heated or rarefied, the colder and heavier air of the surrounding regions rushes in to restore the balance, and thus atmospheric currents are produced. These currents are extremely unstable, blowing without regard to time or direction, and modified and obstructed in a thousand ways by hills, valleys, and other surface irregularities. They are equally unstable in their velocity, varying from the gentlest breeze to the fiercest hurricane which overturns cities and uproots forests. But though characterised by these irregularities over the greater portion of the globe, there are regions over which they pass with wonderful steadiness for months together. The trade-winds which take place within the tropics possess this character, and blow from east to west with little variation of



and creeks by the waves and tides of the ocean, is no sooner left dry by the tide, and exposed to the sun, than it becomes light, and easily acted upon by the wind, which raises it into knolls and ridges beyond the influence of the returning tide. By and by a scanty herbage gathers over the sand, and thus, in course of ages, extensive downs are formed. In a similar manner the wind acts upon the sandy deserts of Arabia and Egypt, continually shifting their surface; and if it sets in from any prevailing direction, these sands are carried forward, year after year, burying trees, fields, and villages, and thus converting fertile districts into barren wastes. When a river enters the sea through a sandy district, it has a tendency frequently to shift its channel; and this tendency is greatly increased by winds damming up the current with drifted sand. Volcanoes occasionally discharge showers of dust and ashes, which, during high winds, are carried over many leagues of surface, or borne out to the ocean. During calm weather volcanic dust and ashes would fall in the neighbourhood of the crater; during high winds they may be deposited at vast distances from their original sources. Such examples as the above are the ordinary actions of wind: the uprooting of forests, the destruction of cities, and the like, are extraordinary, and are caused by whirlwinds and hurricanes.

42. *Frost exercises a slow but permanent influence* in modifying the surface configuration of the globe. When the heat of the surrounding atmosphere falls below 32 degrees of the thermometer, water begins to freeze, and in this state expands. During winter or moist weather, water enters between the particles of all rocky matter at the surface of the earth, and also into the larger fissures; and the expansion of this water by frost separates these particles, and leaves them to fall asunder when the ice is dissolved. This takes place more or less every winter; and there is not a cliff or hill side but bears evidence of this kind of action. The effects of frost in crumbling down rocky material has been long observed: the farmer takes advantage of it to pulverise his soil; and in some districts slate and flagstone are split into thin laminæ by being exposed to the frost.

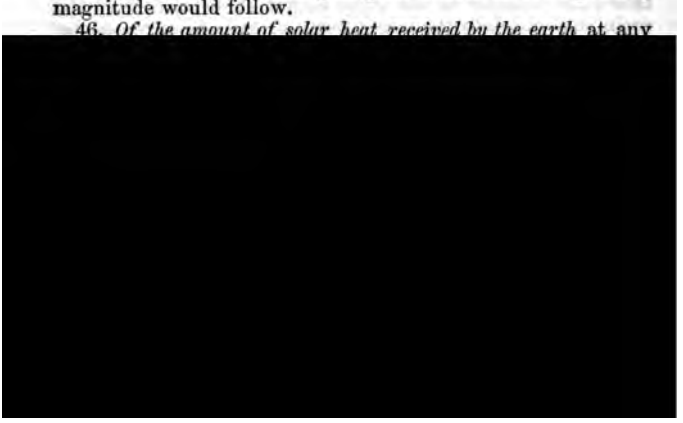
43. *Of the amount of change produced by frost*, it would be difficult to form an estimate; but, taking it over a lapse of ages, there can be little doubt that it has been an important agent. In mountain regions, such as the Alps, its effects are strikingly apparent in the formation of avalanches; and in northern latitudes the iceberg is one of its familiar productions. The action of frost in crumbling down a rocky surface seems slow and insignificant, but when we look

upon the avalanche carrying rocks, gravel, trees, and houses before it, and burying them in one common ruin; when we look upon the iceberg laden with huge stones, and dropping them into the ocean as it dissolves, we are more impressed with its importance, and are enabled to account for certain geological appearances which no other agency could have produced. (See note, page 24.)

44. *Solar heat and light* may, without much impropriety, be classed as atmospheric agents, as the atmosphere is the medium through which they act, and by which they are modified. Water conducts heat faster than air, and air, at the surface of the earth, faster than highly rarefied air at great heights; hence different conditions of the atmosphere may have hitherto conducted more heat to the earth's surface. The quantity of light which reaches the earth depends upon the serenity of the atmosphere, and the height of the sun above the horizon; hence, also, a different condition of atmosphere would produce a different amount of light.

45. *Heat and light are indispensable to vegetable and animal existence;* and the kind and number of plants and animals depend, in a great measure, upon the degree and uniformity of their influence. Heat converts water into vapour, and vapour forms dews, rains, &c. The amount of vapour, and consequently the amount of rain, will depend upon the degree of heat; and hence the heavy periodical rains of the tropics. A higher degree of heat all over the earth would greatly increase the amount of rains, these rains would form more gigantic rivers, and geological effects of corresponding magnitude would follow.

46. *Of the amount of solar heat received by the earth* at any



insensibly, and other times with rapidity and violence. We know, also, that what the chemist has not been able to effect by the most powerful charges of electricity, has been accomplished by the slow and almost insensible effects of the same agent. What takes place in the laboratory of the chemist may be daily occurring in nature. We occasionally perceive the violent effects of electricity during a thunder-storm; but these may be trifling in comparison with what is hourly, but insensibly, taking place among the materials which compose the crust of the earth. We often hear of the disasters of a tropical thunder-storm, where the electric fluid demolishes houses, rends trees, sets fire to forests, or shivers rocks; but these consequences, though startling, produce no extensive terrestrial changes; so that it is to the slow and unseen agency of this power in producing peculiar transformations of metallic and other matter, that its importance in geological reasoning is mainly to be ascribed.

48. *The gaseous constitution of the atmosphere* acts chemically, not mechanically. In its ordinary state, as we have already seen, every 100 parts are composed of 79 nitrogen and 21 oxygen, with a small proportion of carbonic acid, amounting to little more than one part in a thousand. This constitution is essential to animal and vegetable life; hence the student can readily conceive how any extensive alteration of this mixture would operate. Carbonic acid gas is given off by some springs, by volcanic fissures, and by similar sources both in the sea and on dry land. This gas is destructive to life; and consequently shoals of fishes, or herds of animals, coming in contact with any extensive exhalation of it, would be instantly suffocated. Other gaseous fumes are also destructive to life; and bearing these facts in mind, we may be enabled to account for peculiar accumulations of animal remains in certain situations in the rocky strata.

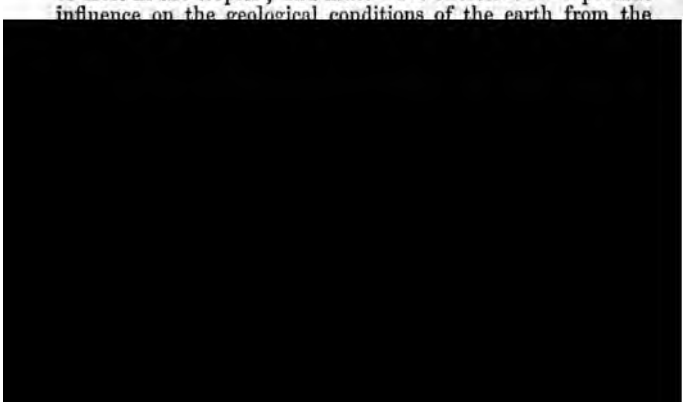
49. *Rocks exposed to the atmosphere* absorb air and moisture, and the action of this air and moisture *weathers*, or dissolves the union of the outer particles. These outer particles fall off by the force of gravity; another set of particles are exposed to the same wasting influence; and thus, year after year, every rock and mountain is losing more or less of its material.

50. *Oxygen and carbonic acid are the principal agents* in this operation. All metallic substances are acted on by oxygen; it tarnishes their surface, gradually eats into their mass, and in time converts them into a loose powdery substance. Iron affords a familiar illustration of this fact: however well polished, if exposed to air and damp, it begins to rust, film

after film, till the whole is in time converted into a reddish powder, called rust, or oxide of iron. All the igneous rocks, and most of the aqueous, contain iron disseminated in minute particles through their mass, and are therefore liable to be acted upon by oxygen. It is this oxide of iron which gives the reddish colour to many rocks and mineral waters.

51. *The formation of many soils is owing to this pulverising power of the atmosphere;* and as their loose matter is washed down by rains and rivers, a new supply is formed by further disintegration of the rocks beneath. We have no means of ascertaining the amount of change produced by the chemical constitution of the atmosphere; but this we know, that it must have exerted itself through all time most powerfully in warm damp climates, and least where the air was clear and arid. Soft clays and shales are easily weathered down; so, also, are all kinds of volcanic rocks; and even granite has been known to be pulverised to the depth of three inches in six years.

52. *The atmospheric agents chiefly instrumental in modifying the crust of the globe,* all, more or less, exert a degrading or wasting influence; that is, a tendency to wear down the surface to a lower level. Wind occasionally presents an exception to this statement, and tends to raise the surface; as in the formation of downs and sand-hills of considerable elevation, like those of Barry at the mouth of the Tay. Atmospheric forces act either mechanically, chemically, or vitally; are universal in their operations, with perhaps the exception of frost in the tropics; and must have exercised an important influence on the geological conditions of the earth from the



manner electricity acts, the action is said to be *electrical;* the reconversion of blue vitriol (sulphate of copper) into metallic copper, as is done in electrotyping, is an example of this kind of action. *Vital* is applied to any sort of action depending on life, whether in animals or vegetables.

WINDS.—Besides the *trade-winds*, blowing within the 25th degree of latitude on either side the equator, there are the *monsoons*, which are merely the trade-winds diverted north or south by the land that lies within these parallels; the *simoom*, a burning pestilential blast, which rushes with fury over the sandy deserts of Arabia; the *harmattan*, a cold dry wind, frequent in Africa and in Eastern countries; the *sirocco*, a hot, moist, and relaxing wind, which visits Italy from the opposite shores of the Mediterranean; the *bize*, a cold frosty wind, which descends from snow-covered mountains, such as the Alps; and *whirlwinds* and *tornados*, that are common to all countries, but most destructive in warm regions.

FREEZING.—Water, at the temperature of 40 degrees, may be said to be stationary as to bulk; but if the temperature be reduced, it begins to expand, till, at 32 degrees, it freezes, and is converted into solid ice, in which state it is 1-14th larger than its original volume. On the other hand, if the temperature be increased, the water is gradually converted into vapour, till, at 212 degrees, it boils, and is rapidly expanded into steam, in which state it is 1700 times its original bulk. Steam can be still further expanded, till almost no known force is able to resist it.

PULVERISE (Lat., *pulvus*, dust)—to reduce to dust or powder. Soil, which is reduced to small particles by the action of frost, is said to be pulverised. So also of rocks.

DISINTEGRATE (Lat., *dis*, asunder, *integer*, whole)—to break asunder any whole or solid matter. The *disintegration* of rocks is caused by the slow action of the atmosphere or by frosts, &c.

DEGRADING, DEGRADATION (Lat., *de*, down, *gradus*, a step)—to take down from one level to another. The degradation of hills and cliffs is caused by rains and rivers; hence water is said to degrade, or to exercise a degrading influence on the land. Degradation and elevation of land are opposite terms.

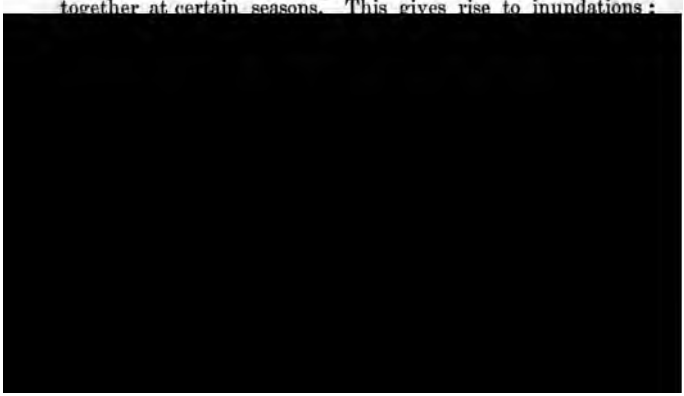
DENUDATION (Lat., *denudo*, I lay bare)—a term sometimes employed as synonymous with degradation, but inaccurately so. For example, *disintegration* strictly applies to that action by which the materials of solid rocks are loosened or separated from each other; *degradation* to the carrying of these materials from a higher to a lower level; and *denudation* to the removal of superficial matter by water, so as to lay bare the inferior strata.

AQUEOUS AGENCIES.

53. AQUEOUS AGENTS, or those arising from the power and force of water, are perhaps not so universal or so complex in their operations as atmospheric; but they are more powerful, and consequently exert a more obvious influence in modifying the crust of the globe. Their mode of action is either mechanical or chemical: mechanical, as when a river wears away its banks, and carries the material to the sea; and *chemical*, when, from gaseous admixture,

water is enabled to dissolve certain rocks and metals. The action of water is sometimes slow and gradual, as in the wearing down of rocks by rain; or rapid and violent, as in the case of river-floods and sea-storms. The effects of rain upon a cliff may not amount to one inch in a hundred years, while hundreds of acres of alluvial land may be swept to the ocean by one river-flood. Water operates variously: sometimes by itself, as in rivers; sometimes in union with the atmosphere, as during land and sea-storms. Its power as a geological agent is most obvious in the case of rains, springs, rivers, lakes, waves, currents, and tides; and the results of these agents are distinguished as *meteoric, fluviatile, lacustrine,* or *oceanic.*

54. *Rain, hail, snow, and all atmospheric vapours, exercise a degrading influence* on the earth's surface. By entering the pores and fissures of rocks, they soften and gradually dissolve their surface, and thus materially assist the operations of frosts, winds, &c. Rain, accompanied by high winds, acts with greater force; snow, from accumulating during frost, and suddenly dissolving during fresh weather, sometimes occasions violent floods and inundations. Floods arising from the melting of snow are generally very destructive, for, during the season when they occur, the surface is soft and loose, and much more liable to be carried away. Rain and other vapours are indispensable to the growth of vegetables, and when accompanied with sufficient warmth, a luxuriant and gigantic vegetation, like that of the tropics, is the result. The amount of rain which falls on the earth's surface is exceedingly varied, ranging from 20 or 30 inches to several feet per annum. In tropical regions, rains are periodical; that is, fall for weeks together at certain seasons. This gives rise to inundations:



earth either by rents, fissures, or other openings in the surface. The water which falls in rain, snow, &c. partly runs off, and partly sinks into the crust, where it collects in vast quantities, and ultimately finds its way again to the surface by springs. Springs issuing from strata at great depths are said to be *deep-seated;* those from clay or gravel are *shallow.* Some only flow during or shortly after rains, and are said to be *temporary;* some flow always, and are *perennial*; while others flow and ebb, and are said to be *intermittent.*

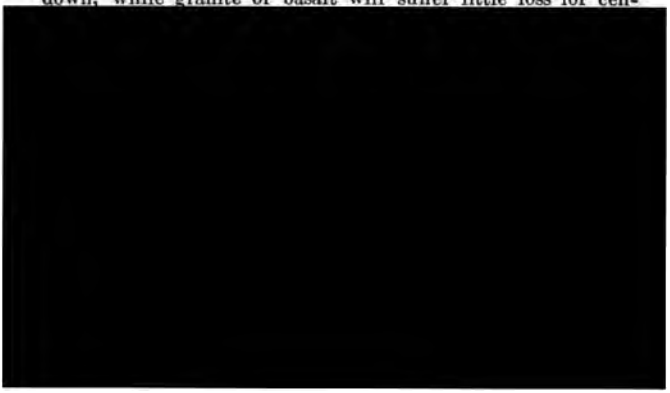
57. *The characters in which geologists have principally to consider springs* are cold, thermal, and mineral. Cold springs have a mechanical action when they cut out channels for themselves; and they act chemically when, for example, they contain carbonic acid, and dissolve portions of the rocks through which they pass. All petrifying springs—that is, such as convert wood and bones into stony matter—act chemically. Thermal, or hot springs, occur in numerous parts of the world (England, Iceland, Germany, Switzerland, Italy, Hindostan, &c.), and also act mechanically and chemically, but with much greater chemical force than cold springs. Mineral springs may be either cold or hot, and take their name from the circumstance of their waters holding some mineral or earthy substance in solution.

58. *Mineral springs, geologically speaking, are by far the most important,* as, from their composition, they indicate the kind of rocks through which they pass, while they more or less influence all deposits or waters into which they flow. Thus, some contain iron, and are said to be ferruginous, or chalybeate; some copper (cupriferous), some lime (calcareous), some salt (saline), while others give off sulphureous vapours; and so on with almost every known mineral. Those issuing from strata containing iron or lime are more or less impregnated with these substances; and when they arrive at the surface of the earth, and their waters become exposed to the air, the ferruginous or limy matter is deposited along their courses, or is carried down to the nearest river or lake. If layers of mud, sand, or gravel be forming in such a lake, these layers will be impregnated with the matter of the springs; hence geologists speak of ferruginous, calcareous, or saliferous strata. Mineral springs may therefore be said to exert a twofold influence: first, by dissolving and carrying away matter from the strata beneath; and, second, by adding that matter to the strata which are now being formed on the surface. The student will thus perceive the manner in which springs act in modifying the crust of the earth; and in proportion to their size, the softness of the strata through which

they passed, and the degree of heat they had acquired, so must the extent of their influence have been at any former period.

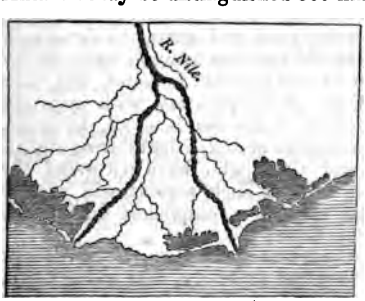
59. *Rivers are the most important aqueous agents* employed in modifying the surface of the globe. Springs, as they issue into open day, naturally seek a lower level; and numbers of them meeting in one channel, form streams, which again join in some still lower valley, where their union produces rivers of various sizes. Rivers may be said to be a species of natural drainage, by which the superabundant moisture which falls on the land is again returned to the sea. They are of all dimensions; in breadth from a few feet to several miles, so shallow that a boy might wade them, or so deep as to float the largest ships, and ranging in length of course from fifty or sixty miles to as many hundreds.

60. *The geological action of rivers is twofold;* first, by wearing down the land through which they pass, and then by carrying down the material to lakes and seas. Both their degrading and transporting force depends upon their velocity. For example, it has been calculated that a force of 3 inches per second will tear up fine clay, 6 inches will lift fine sand, 8 inches sand as coarse as linseed, and 12 inches fine gravel; while it requires a velocity of 24 inches per second to roll along rounded pebbles an inch in diameter, and 36 inches per second to sweep angular stones of the size of a hen's egg. Rivers, during floods, often acquire a much greater velocity than this, and stones of considerable weight are then borne down by their currents. The degrading power of running-water depends also upon the kind of material through which it flows; loose soil, clay, and sandstone being easily worn down, while granite or basalt will suffer little loss for cen-



river flows in a channel upwards of 150 feet deep and 160 yards wide, for a distance of seven miles; and this channel has evidently been produced by the action of the river. Such effects as the above are produced by the general or ordinary action of water; but when rivers are swollen by heavy rains, by the sudden melting of snow, and the like, then they act with extraordinary violence. In these cases they overflow their banks, rush with a velocity of 20 or 30 feet per second, tear up the soil, and sweep before them trees, animals, houses, and bridges. The water of all rivers which exert a degrading influence is more or less turbid, and an idea of their power may be formed by observing this fact.

61. *The matter which rivers carry down* is either deposited along their banks, in lakes, or in the ocean. If they flow sluggishly along a flat valley, the mud and sand which their waters contain gradually falls to the bottom, and there rests as sediment. This sedimentary matter forms what is called *alluvial* land, and most of the flat and fertile valleys in the world have been so produced. Again, when a lake occurs in the course of rivers, the sediment is there collected, and the water issues from the lake as if it had been filtered. In progress of time, lakes are filled or *silted* up with this sediment, and their basins appear first as marshes, and latterly as alluvial land. But whatever quantity of matter may be deposited in valleys or lakes, the greatest amount will always be carried down to the ocean, and deposited at the mouth of the river or along the shores. The heaviest material, such as gravel, will fall down first, then the lighter sand, and ultimately the finest mud. The mud of the Ganges discolours the Bay of Bengal to a distance of 60 miles from its mouth; and according to Captain Sabine, the muddy waters of the Amazon may be distinguished 300 miles from the shore.



62. *The consequence of this continual seaward-carriage of sedimentary matter* is, that at the mouths of most rivers there are alluvial formations, known by the name of *deltas;* such as those of the Nile, the Ganges, the Niger, &c. They take their name from their resemblance in shape to the Greek letter Δ (delta); and fre-

quently extend over vast surfaces—that of the Ganges being about 200 miles in one direction by 220 in another. They consist of alternate layers of sand, gravel, or mud, according to the kind of material the river carries down. The foregoing cut represents the Delta of the Nile, which is generally regarded as the type of all similar deposits.

63. *The geological results effected by the agency of running water* are ceaseless and universal. Rivers are gradually wearing down the hills and higher lands, and as gradually silting up lakes and low tracts of valley land. They lay down beds of gravel, sand, or mud; and these beds, again, enclose trees, plants, the bones and shells of animals, in greater or less abundance. As rivers now act, so must they have always acted, and to this kind of agency must we ascribe the formation of many of the rocks (with their fossils) which now form the crust of the earth both at great depths and at distances now far removed from the sea. We have no actual knowledge of the rivers of the ancient world; but, judging from the extent of sedimentary rocks, they must have been much more gigantic than most of those now existing.

64. *Waves, currents, and tides, are also powerful geological agents.* Waves are continually in action; and according to their violence, and the materials composing the sea-coast, so is the amount of change produced. Cliffs of sandstone, chalk, clay, or other soft rock, are, year after year, undermined by their force; masses fall down, are soon ground to pieces, and swept off by every tide; new undermining take place, new masses fall down, and thus thousands of acres of land have been reduced to a level with the sea.

that tidal currents convey the disintegrated matter to more sheltered bays and creeks; and that oceanic currents convey floating material, such as drift-wood, plants, and dead animals, from one part of the ocean to another. Tides rise and ebb from 4 to 40 feet; they enter into certain rivers for many miles; and thus a mingling of fresh water and marine deposits take place. As at present, so in ages past; and by diligently studying the effects produced by waves and tides, the student will be enabled to account for many appearances which the sedimentary rocks present.

EXPLANATORY NOTE.

THE ACTION OF WATER is said to be *meteoric* when it acts through the atmosphere; *fluviatile* (*fluvius*, a river) when it acts by running streams or rivers; *lacustrine* (*lacus*, a lake), by pools or lakes; and *oceanic*, when by the ocean.

SILT.—Mud or sand carried down by any river, and deposited either along its banks or in lakes, is called silt; and when a lake becomes filled with this matter, it is said to be *silted up*. Silt is generally applied to matter calmly or slowly deposited.

DEBRIS (French)—a term applied to the loose material arising from the disintegration of rocks.

ALLUVIAL (Lat., *luere*, to wash, and *ad*, together). Land washed or brought together by the action of water is said to be alluvial. Most of the *straths* and *carses* in Scotland, and the *dales* in England, are alluvial; as are also the *deltas* of all such rivers as the Nile, Ganges, Niger, Mississippi, &c.

SEDIMENT (Lat., *sedere*, to sit or settle down)—matter settled down from solution in water. If water containing mud be allowed to stand without agitation, the mud will gradually fall to the bottom, and become sediment. Rocks which have been deposited after this manner, such as sandstone, are said to be *sedimentary*.

DEPOSIT (Lat., *de*, down, and *positus*, placed)—applied to matter which has settled down from water. Mud, sand, gravel, &c. are all deposits, and are distinguished by the kind of agency which produced them; such as fluviatile (river) deposits, lacustrine (lake) deposits, marine (sea) deposits, and littoral (sea-shore) deposits.

IGNEOUS AGENCIES.

66. Atmospheric and aqueous agencies may be said to exert themselves similarly in modifying the crust of the globe. Both have a tendency to wear down the dry land; and if this influence went on year after year, without any counteracting force, a time might arrive when hills and plains would be reduced to one uniform level. But the system of nature is beautifully balanced in all its parts, and as one set of agents *degrade*, another are employed to *elevate*. Thus the layers of loose material which *are at one time* spread out in the bottom of

lakes and seas, is at another raised into open day, to form new lands for the support of vegetable and animal existence. The principal agent employed in this elevating process is the *Igneous*, or that which depends upon some deep-seated source of fire. Hereafter we shall notice the opinions which have been advanced concerning the origin of subterranean fire; at present we have merely to do with its sensible effects.

67. *Igneous agency may exert itself either chemically or mechanically;* chemically, as in the production of new compounds, gaseous admixtures, &c.; mechanically, as when it elevates and fractures the solid crust of the earth. Its mode of action may be considered under three heads; namely, Volcanoes, Earthquakes, and Gradually Elevating Forces.

68. *Volcanoes* may be described as vents of subterraneous fire, through which smoke, gaseous vapours, cinders, ashes, stones, and rocky matter in a state of fusion, are discharged. The explosive or expansive force of the internal fire forms a vent for itself in the first instance; this opening is termed the *crater*, and the matter discharged, gradually collecting around it, produces a mountain of a towering or conical form, like that described by the following figure.

America. In these ranges, some of the vents are in active operation, and others have become dormant; so that we are insensibly led from the crater vomiting forth smoke and lava to those now cold and dormant, and thence again back to distant eras when all mountain chains were produced by the same kind of forces. Indeed no one can look upon the mere outward appearance of Ætna and Vesuvius on the one hand, the Alps, the hills of central France, and the hills of the Scottish Lowlands on the other, without at once assigning their origin to similar causes.

70. *Volcanic forces not only elevate but fracture and contort* the originally plane strata, at the same time that they throw up rocky matter which is not arranged in distinct layers. It has been already stated that water has a tendency to lay down the material which it transports in flat or level strata; hence the sedimentary rocks will originally partake of this level character. Suppose, then, that the following engraving represents a part of the earth's crust not broken or upheaved by volcanic forces, the same

portion will present a very different appearance when fractured and elevated by these causes. Here the sedimentary strata are not only thrown out of their original level position,

but are bent, broken asunder, and in some places overlaid by discharges of volcanic matter; hence a very obvious distinction exists between rocks of *aqueous* and rocks of *igneous* origin.

71. *A volcano may at one time discharge ashes*, at another time rock fragments, and at a third molten lava; and it is true that these different materials may be found on its sides arranged in *something like* strata; but they do not present this

regularity for any distance. Sedimentary strata, on the other hand, preserve their character and continuity over many miles of country, showing a calm and tranquil origin in comparison with those masses produced by volcanic fusion. Other distinctions between aqueous and igneous rocks will hereafter be pointed out to the student; but at present he cannot fail to perceive that sand, clay, mud, and other matter deposited from water, must be more equally and flatly laid down than cinders, ashes, and lava, which are vomited forth without order or arrangement.

72. *There are at present upwards of two hundred volcanoes in active operation.* The greater number of these are to be found in the mountain ranges of South America, along the western coast of North America, and in the Southern Pacific. In central Asia there are also several vents; and Ætna, Vesuvius, and Hecla, are well-known examples in Europe. The number of active volcanoes is nothing, however, in comparison with what once existed; for there is scarcely a country (Italy, France, Britain, West India Islands, the Azores, Iceland, &c.) that does not give evidence of innumerable volcanic craters which have long since ceased to modify the crust of the globe. Even these dormant vents are insignificant in comparison with the still older mountain ranges of the Grampians, Pyrenees, Uralian, Himmaleh, Andes, and other chains which must have been upheaved by the same subterranean forces.

73. *Of the elevating power of volcanoes* we have many examples within the historical period, and comparing active volcanic hills with ancient ranges, we may arrive at some idea of the enormous power exerted by igneous forces in the earlier ages of the world. During an eruption of Ætna,

tions, a sudden outburst of volcanic action, which lasted several months, terminated in leaving six hills, varying from 300 to 1600 feet in height above the old plain. As on land, so also in the ocean; and the student will hereafter find that many volcanoes have been known to arise from the sea, that the bottom of the sea has been upheaved by the same influence, and that many islands, such as those of the Pacific and Atlantic, are mere accumulations of volcanic matter. "Owhyhee," says De la Beche, "is a magnificent example of such an island: the whole mass, estimated as exposing a surface of 4000 square miles, is composed of lava, or other volcanic matter, which rises in the peaks of Mouna Roa and Mouna Kaa to the height of between 15,000 and 16,000 feet above the level of the sea."

74. *Earthquakes are most important geological agents,* though their origin and mode of action is scarcely so obvious as those of volcanoes. The theories which have been advanced to account for such phenomena will be elsewhere adverted to; here it is sufficient to state, that, though they occur in all parts of the world, they are much more frequent and violent in the region of active volcanoes. Earthquakes are strictly mechanical in their mode of action, upheaving some portions of the crust and depressing others, causing rents and fissures, altering the course of rivers, elevating the bottom of the sea to open day, and submerging dry land beneath the ocean. They are sometimes so gentle in their operations, that a slight tremulous motion of the earth is all that is perceived; at other times the shock is so violent, that the surface configuration of wide districts is completely altered, and the works of man become masses of ruin. Volumes might be filled with accounts of earthquakes and their disastrous consequences; we shall simply notice a few historical facts to show their importance. In 1596 several towns in Japan were covered by the sea; in 1638 St Euphemia became a lake; in 1692 Port Royal, in Jamaica, was submerged; in 1775 the great earthquake of Lisbon sank many parts of the Portuguese and African shores 100 fathoms under water; in 1819, at the mouth of the Indus, a large tract of country, with villages, was submerged, while a new tract was elevated, called the "Ullah Bund;" in 1822 about 100 miles of the Chili coast was elevated to the height of four or six feet; and in 1843 several of the West India Islands were fearfully convulsed, and a vast amount of life and property destroyed.

75. *The general effect of earthquakes,* like that of volcanic forces, is to render the crust of the earth irregular in surface,

by depressing some portions and by elevating others. It requires little effort of imagination to conceive how a level tract of country might, by a few shocks, be converted into abrupt heights, rents, chasms, and hollows, or even sunk many fathoms beneath the ocean. Earthquakes in the vicinity of the sea are generally accompanied with violent agitation of the water, and waves of enormous height are rolled upon the land (60 feet in the Lisbon earthquake), tearing up the surface, and forming masses of loose material.

76. *As earthquakes now act, so must they have done in all time past;* and if the great mountain ranges prove the existence of more extensive volcanic agency, we are warranted to conclude that earthquakes were also more frequent and disastrous in the earlier ages of the world. If fissures, chasms, and subsidences be at present produced by earthquakes, the student will have little difficulty in accounting for the numerous rents and breakings which occur in the solid strata in regions where volcanoes and earthquakes have long since ceased to exert their agency.

77. *Gradually elevating forces* appear to be intimately connected with those which produce volcanic eruptions and earthquakes. The term is applied where we find tracts of country and shores of the sea undergoing a slow process of elevation, without being accompanied with any perceptible violence. Mr Lyell has discovered instances of this kind of elevation along the shores of the Baltic, where places, which a century ago were on a level with the sea, are now several feet above it, and where even a change of a few inches has taken place since 1820.

78. *To what extent such forces may have operated in times*

east coast of England, and the coast of France and Portugal, there is a very remarkable beach of this description, from 40 to 50 feet above the present sea-level, and presenting a sort of step or terrace, which is easily traceable sometimes for miles together. This terrace is composed of rounded pebbles, gravel, sand, and sea-shells, and such material as usually compose the beaches at the present day.

79. *As some parts of the land may be elevated, so others may be depressed;* and consequently we find stumps of trees under the present sea-level, clearly showing that the land on which they grew had been submerged. But whether these ancient elevations and depressions have been accomplished in one hour or in many years, whether quietly or with violence, geologists have not yet been able to determine.

EXPLANATORY NOTE.

VOLCANO, from *Vulcan*, the god of fire, who was supposed by the ancients to reside in a cavern under Mount Ætna, and to forge thunderbolts for Jupiter.

LAVA, an Italian term, now universally applied to those masses of melted matter which are discharged by volcanoes during an eruption. Loose fragments of rocks, cinders, dust, and ashes, are comprehended under the term *scoriæ*.

CRATER (Gr., *krater*, a cup or bowl)—the mouth or vent of a volcano; so called from the resemblance which its shape bears to an ancient drinking bowl. The craters of volcanoes have, in general, one edge a little lower than the other, owing to the prevailing winds carrying the greater portion of the light material to the opposite side.

ORGANIC AGENCIES.

80. Compared with the other classes of agents which have been described, the Organic are comparatively unimportant in modifying the crust of the globe. They exert an elevating or accumulating influence, and may act either on the dry land, in fresh or in salt water, according to the nature of the vegetables or animals from which they result. They are comparatively slow in their operations, but produce the most interesting class of phenomena with which geological research has made us acquainted. Organic agency presents itself under two great heads—namely, Vegetable and Animal.

81. *Vegetable growth acts in two ways:* first, by forming accumulations of matter, such as peat; or, second, by protecting the soil from the degrading power of rains and winds. Extensive areas of sand-drift would be continually shifting, were it not for the vegetable sward which gathers over their surface; and *all soils*, during seasons of drought or rain,

would be liable to be blown or washed away, were it not for the grassy turf which covers them. Marine plants are extremely perishable, and exert no perceptible influence on the earth's crust. Terrestrial plants are of a very different character both in point of size, number, and material; and to them are chiefly owing the vegetable deposits in all ages of the world.

82. *Trees and plants are annually carried down by rivers, and deposited* along with the layers of sand and mud which have already been noticed. The *rafts* of the Mississippi are frequently several miles in length, and from 6 to 10 feet thick, being composed of trees, roots, and brushwood. All marshes and shallow waters give birth to innumerable aquatic plants, which grow and decay from year to year, till, in the course of centuries, their remains form thick accumulations of peat. Peat bogs, of many miles in surface, and from 4 to 20 feet in thickness, are frequent in Scotland, Ireland, and other countries, and contain trees and the remains of animals which once inhabited the country. Vegetable growth is greatly influenced by climate, being more prolific and gigantic in warm than in cold regions, and being also entirely different in character. While, therefore, peat is forming in the bogs of Ireland, the Mississippi is carrying down the pines of America, and the Ganges the palms, canes, and tree-ferns of the Indian jungle.

83. *Of the vegetation of past eras* we can only judge from the fossil remains found in the solid rocks; and, comparing that of the coal strata with what now exists, we are war-

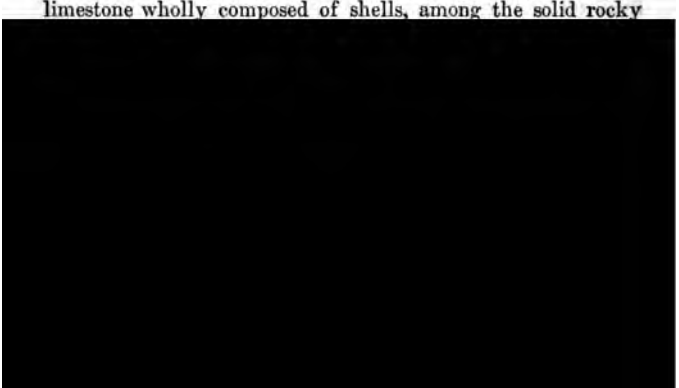
It is not in this light, therefore, that animal existence may be said to be influential in modifying the crust of the earth; and we may reckon of slight importance all the skeletons of the larger animals which are deposited along with the mud, sand, and gravel in the bottoms of existing lakes and seas. It is the minutest forms of life which are mainly instrumental in forming deposits of this class; such as the coral-insect, shell-fish, and some crustaceous animals.

85. *By the labours of the coral animalcule* are formed those extensive reefs of solid coral, or limestone, well known to the navigators of the Pacific. These reefs rise in masses of various shapes; sometimes as islets, at other times as circular belts enclosing a lagoon or lake of salt water, but more frequently in long abrupt ridges from 20 to 100 feet in thickness. The great reef, which follows the line of the northern coast of New Holland, is more than 1000 miles in length, in the course of which there is one continued portion exceeding 350 miles, without a break or passage through it. The animalcule is scarcely so large as a pin's head; it is star-shaped, is of a soft gelatinous structure, and myriads of them unite in their operations to form a single branch of coral. By examining a piece of coral, its surface will be found dotted with small star-like openings: each of these contains a single animal, and the space between them is covered by the membrane above referred to. These animalcules have the power of secreting limy matter from the waters of the ocean; they are incessantly at action, and many of the reefs rise several feet in the course of a few years. They do not commence their labours at great depths, but attach their structures to rocks from 60 to 100 feet below the surface; and thus the coral reefs partake of the shape of the submarine ridges on which they are founded. As their structures approach the surface, the waves and currents of the ocean detach large pieces, which are either drifted on the land, and form coral-beaches, or are piled upon the surface of the growing reef, till it rises above the sea. When the animal reaches the surface it ceases its operations, and the subsequent elevation into islands and dry land is performed by the waves and tides, and by the elevating forces described in the preceding section.

86. *Coral is almost entirely composed of pure limestone*, and is found in all stages of solidity, from an open porous mass, with the live animal upon it, to a hard and compact limestone, with scarcely a trace of its animal origin discernible. There are many species of the coral animalcule, each variety rearing its structure after a different form; and from this fact such names have been given as tree coral, fan coral, organ-pipe

coral, brain coral, &c. Whatever be the shape, the substance formed, and their mode of action, is the same. They are found largely over the Southern Pacific, in the Indian Sea, the Red Sea, and other portions of the ocean. As at present, so in former ages of the world; and the student will hereafter find that many of the beds of limestone now deep in the crust of the globe, have been formed by the same kind of organic agency.

87. *Shell-fish, like the coral animal, have the power of secreting limy matter* from the ocean. In the former case, the secreted matter forms a covering or enclosure for the animal; in the latter, the animal is external, and the structure forms a mere groundwork for its operations, and a wider field for the increase of its kind. There is an immense variety of shell-fish, but only a few varieties exist in great numbers, and it is by the agency of these that shell-beds are formed. The oyster, muscle, and cockle, are familiar examples; they live in great shoals or beds, covering from a few acres to many miles of the bottom of our seas and friths. Zoologists have found that most shell-fish live in shallow waters around the shores; and from this habit they are more liable to be covered by the material borne down by floods and rivers. In raised beaches, and in deltas, we actually find such accumulations of shells, sometimes several feet in thickness, and presenting the same appearance as when they lived and multiplied in the waters. If, then, extensive layers of shell-fish now exist, and if they are sometimes found imbedded in the alluvial matter of deltas and lakes, the student will be better enabled to account for the occurrence of thick masses of shells, or limestone wholly composed of shells, among the solid rocky



89. *The formation of coral-reefs and shell-beds is a gradual and ordinary operation;* but shoals of other fishes may be entombed during violent storms, or during submarine volcanic eruptions, which are attended by noxious vapours, heat, and a suffocating agitation of the mud of the ocean. The modes in which vegetable and animal life may affect the crust of the globe are extremely complex and varied, but the above are the most obvious and important.

RECAPITULATION.

90. *As detailed in the preceding section,* the causes chiefly employed in modifying the structure of the globe may be divided into four classes—ATMOSPHERIC, AQUEOUS, IGNEOUS, and ORGANIC. The former two exert a degrading or wasting influence, and if not counterbalanced by other forces, would ultimately wear down the dry land to a level with the ocean; the latter exert an elevating or accumulating influence, and thus maintain that elevation and diversity of dry land essential to animal and vegetable life. To assist the memory, these agents may be briefly arranged as follows :—

DEGRADING CAUSES.		ELEVATING CAUSES.	
Atmospheric.	*Aqueous.*	*Igneous.*	*Organic.*
Winds,	Rains, Snow, &c.	Volcanoes,	Vegetable accumulations, as
Frosts,	Springs,	Earthquakes,	peat, &c.
Heat and Light,	Rivers,	Gradually elevating forces.	Animal, as coral-reefs, shell-beds, &c.
Gaseous Admixtures.	Waves, Currents, Tides.		

91. *If, then, on the one hand, winds, frosts, rains, rivers, and waves* be continually wasting down the solid crust, and depositing the debris in layers along the bottom of lakes and seas; and if, on the other, these layers be consolidated by pressure, by chemical processes, or by heat, and be then elevated into dry land by volcanoes and earthquakes, it must be obvious that the surface of the globe is in a state of perpetual change. These changes may be slow and imperceptible, or sudden and obvious; but in either way the appearances exhibited by the earth's surface must be very different now from what it was many thousand years ago. What was then covered by the ocean, may now be dry land; and what was dry land, may have since been ocean, and may now be dry land again. These changes will be manifested by the kind of layers or rocks deposited at each successive period in the bottom of the sea; hence the geological history of the

world can only be discovered by the study of these strata. But as these strata were upheaved by volcanic agency, rocky masses of igneous or volcanic origin are frequently mingled with them; hence we find not only stratified rocks from deposition in water, but unstratified, the result of igneous fusion. Again, all strata originally deposited by water will contain more or less the remains of plants and animals which flourished during the period they were deposited; and the consideration of these petrifactions affords the geologist an idea of the kind of life which then peopled the surface of the earth, or inhabited the waters. These unstratified and stratified rocks, with the animal and vegetable remains which they contain, form the solid crust of the globe—the structure, composition, and formation of which it is the province of geology to consider.

EXPLANATORY NOTE.

SECRETION (Lat., *secretus*, separated or set aside). Both animals and vegetables are said to secrete certain substances. Coral, for example, is an animal secretion composed of lime, which the animalcule has the power of separating from the water of the ocean; resin and gum are vegetable secretions.

EXUVIÆ (Lat., *cast clothes*). In Zoology this term is applied to the external integuments of animals which are periodically shed or cast off, such as the skin of the snake, the crustaceous covering of the crab, &c.; but in geology it is employed to designate fossil animal remains of whatever description.

MINERAL SUBSTANCES COMPOSING THE EARTH'S CRUST.

the terms *igneous* and *volcanic*. The following engraving represents the appearance which the stratified and unstratified rocks present in a section of the earth's crust.

Unstratified. Stratified.

93. *All rocks, whatever be their origin, have three characters* under which they are viewed by the geologist—namely, the *Mechanical, Mineral,* and *Chemical;* and though it is impossible, in an elementary work of this kind, to enter fully into the consideration of these characters, still it is necessary that the student should be in some degree acquainted with the technical terms which are employed to designate these characters.

94. *The mechanical structure of rocks* is that which presents itself in the general appearance of the mass as it occurs in the earth, or in portions of the mass when it is broken up by artificial means. It has nothing to do with the composition, and merely considers the appearances presented, whether the rock be roofing-slate, chalk, or coal. For example, some rocks are arranged in layers, and these layers can be split up into still thinner plates, as slate; others occur in columns, like the basalt of Staffa and the Giant's Causeway; and these columns can be broken up into small prismatic pieces. This structure is purely mechanical, and has been divided by geologists into the external and internal—the former having reference to the mere outward form, and the latter to the shape of the smaller fragments into which the mass can be broken. The external structure of coal, for instance, is stratified, but the internal structure varies; caking coal breaking up into small cubes or square pieces, splint coal into thin slaty divisions, and cannel coal into irregular fragments, having a shell-like surface.

95. *The terms employed to describe these varieties of structure* are useful, in as far as they enable one writer to make himself understood by another. The following are those of most frequent occurrence:—

Massive, occurring in large masses of no determinate form, as granite.
Amorphous, without any regular shape; amorphous and massive are very similar terms.

(Scott) Argilla gives out a peculiar odour of breathed upon, this being a test of the presence of Alumina. Calx

any rock may be ascertained by applying to the

Cuboidal, in square masses resembling cubes, as some greenstones.

Prismatic, occurring in masses, with faces and angles like a prism.

Columnar, in columns or pillars, like basalt. Where the pillars are not very distinct and regular, the term *sub-columnar* is used.

Stratum, bed, seam, and layer. These are nearly synonymous terms, all conveying the idea of being spread or laid out in parallel masses, as sandstone, slate, &c.

Schistoze, fissile, slaty, laminar, are employed to describe rocks capable of being split up into thin plates or divisions like slate.

Foliated, when the laminæ or slates split up into still thinner leaves.

Squamose, when the fragments have a scaly appearance, like mica.

Fibrous, having a fibrous texture, like asbestus; *acicular*, when the fibres have a distinct needle-shaped appearance.

Vesicular, cellular, when the texture of the rock is full of small cells or vesicles.

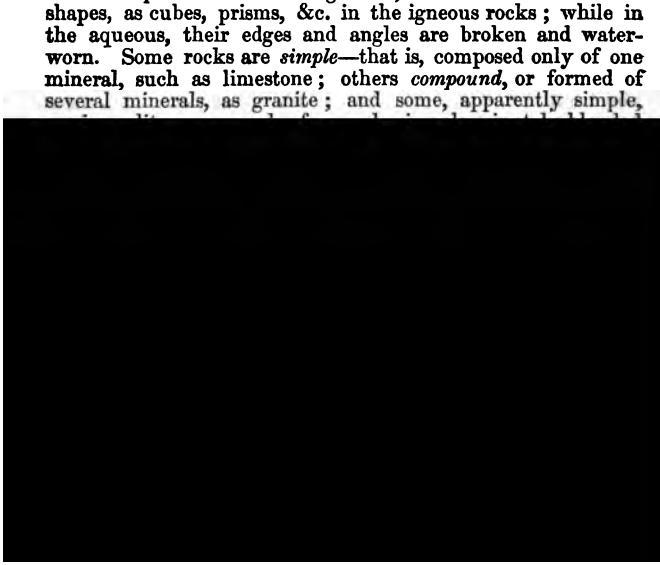
Granular, when the texture is made of distinct grains, as granite.

Saccharoid, when the grains have a uniform crystalline aspect, like loaf-sugar.

Porous, of an open texture, or full of pores, as pumicestone.

Friable, when easily broken down; *earthy*, of a soft dull texture; and *compact*, when of a close and firm texture.

96. *The mineral character of rocks* has reference to the number and aggregation of the simple minerals of which they are composed. A piece of granite, for example, is composed of distinct crystals of *felspar*, *quartz*, and *mica*, which are said to be simple minerals. In general, minerals occur in fixed shapes, as cubes, prisms, &c. in the igneous rocks; while in the aqueous, their edges and angles are broken and water-worn. Some rocks are *simple*—that is, composed only of one mineral, such as limestone; others *compound*, or formed of several minerals, as granite; and some, apparently simple,



the room of mica; granite is then called *syenite*. Hornblende is so named from its horny fracture.

Actynolite, so called from the pointed or thorny appearance of its crystals; it is of a greenish-gray colour, and found in some of the early slates.

Augite, a greenish mineral found in many igneous rocks; it is the type of a class to which hornblende and actynolite belong.

Diallage, also called *Schiller Spar*, an olive, blackish, or yellowish-green mineral of a foliated structure, and having a metallic lustre.

Schorl, occurs in black prismatic crystals; is brittle and lustrous, and becomes electric by heat and friction.

Chlorite, so called from its greenish-black colour; it is either of a crystallised or foliated structure; and in the latter state it forms the greater portion of that greenish slate called chlorite slate.

Green-earth, a greenish earthy mineral allied to chlorite, which enters largely into the composition of many trap-rocks.

Talc, a transparent mineral resembling mica, but softer, and not elastic.

Steatite; all rocks containing this mineral feel greasy or soapy, and are thus easily distinguished; they are sometimes called *soap-stones*.

Garnet, a reddish or wine-coloured mineral found in some mica slates and volcanic rocks.

Carbonate of lime; pure marble, chalk, &c. are carbonates of lime.

Carbonate of magnesia; lithographic limestone is a compound of carbonate of magnesia and carbonate of lime.

Sulphate of lime; gypsum, or plaster of Paris, is sulphate of lime.

Chloride of sodium; common salt is chloride of sodium; it is found in sea-water, and in masses constituting rock-salt.

Bitumen, an inflammable mineral, found either liquid, as in petroleum or rock-oil; solid, as in asphalte; or mixed, as in common coal.

Iron, oxide and sulphurets of; rust is an oxide of iron; pyrites, or those little yellow cubes found in roofing-slate, are sulphurets.

98. *The most abundant rocks* are formed by the aggregation of the above minerals. It would be impossible to convey an adequate idea of these rocks by a mere verbal description; and at this stage the student should endeavour to make himself familiar with the following rocks (of which there are many varieties), by the inspection of actual specimens:—

GRANITE,	FELSPAR ROCK,	QUARTZ ROCK,
SYENITE,	CLAYSTONE,	SANDSTONE,
GREENSTONE,	HORNSTONE,	CLAY-SHALE,
BASALT,	PITCHSTONE,	SLATE,
HYPERSTHENE ROCK,	GNEISS,	FLINT,
DIALLAGE ROCK,	MICA SCHIST,	CHERT,
SERPENTINE,	CHLORITE SCHIST,	LIMESTONE,
WACKE,	HORNBLENDE SCHIST,	COAL.

99. *The chemical character of rocks* has no reference either to their mechanical structure or mineral aggregation. According to the deductions of chemistry, all bodies in nature, whatever their structure or appearance, are composed of

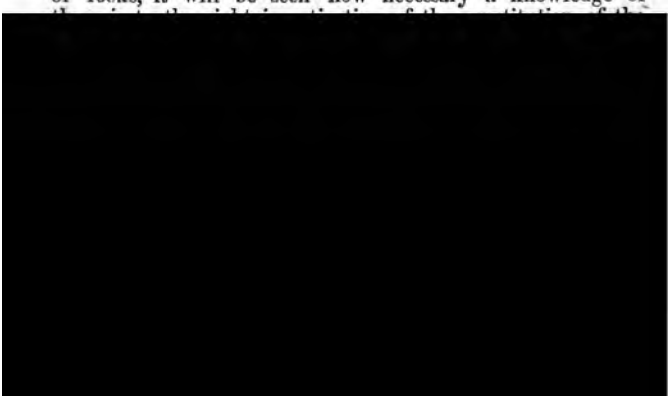
fifty-four simple or elementary substances. Granite, mineralogically speaking, is composed of quartz, felspar, and mica; but these three minerals are each composed of several chemical elements—quartz, for example, being a compound of the gaseous body oxygen, and a metal called silicum.

100. *Of the elementary bodies,* under the ordinary pressure and temperature of the atmosphere, there are—

Five *gaseous*—hydrogen, oxygen, nitrogen, chlorine, and fluorine;
Seven *non-metallic,* liquids and solids—bromine, iodine, sulphur, phosphorus, selenium, carbon, and boron;
Thirteen *solid metalloids,* which unite with oxygen to form the earths and alkalies—sodium, potassium, lithium, aluminum, silicium, yttrium, glucinium, thorium, calcium, magnesium, zirconium, strontium, barium;
Twenty-nine *metals,* which are all solid save mercury—manganese, zinc, iron, tin, cadmium, arsenic, antimony, copper, molybdenum, uranium, tellurium, chromium, cerium, nickel, vanadium, cobalt, lead, tungsten, titanium, mercury, columbium, bismuth, osmium, silver, palladium, rhodium, platinum, gold, and iridium.

101. *Only a few of the fifty-four so-called elements* enter largely into the composition of the rocky masses which constitute the crust of the globe. The most prevalent are oxygen, carbon, sulphur, aluminum, silicium, potassium, sodium, calcium, magnesium, and iron. Of these, oxygen is by far the most prevalent; it is found in combination with every other substance, and is supposed to constitute fully one half of the ponderable matter of the globe.

102. *From what has been stated* in the foregoing paragraphs respecting the mechanical, mineral, and chemical characters of rocks, it will be seen how necessary a knowledge of



them broken and water-worn in gneiss, and concludes that gneiss must have been formed of the disintegrated particles of granite. Again, to the chemist, geological conclusions and mineral classification are but secondary objects; he takes up the simple minerals, and resolves them into their simplest elements, and finds that quartz consists of silicium and oxygen; felspar of silica, alumina, lime, potash, oxide of iron, and water; mica of silica, alumina, magnesia, potash, oxide of iron, and oxide of magnesia. A knowledge of these chemical facts also greatly assists the geologist, as they enable him to account for many changes which take place among rocks, and from whence their materials have been derived. For instance, iron and clay-slate are not perceptible in granite; yet, by chemical means, the ores of iron and clay-slate may both be derived from the felspar and mica which constitute the granite.

EXPLANATORY NOTE.

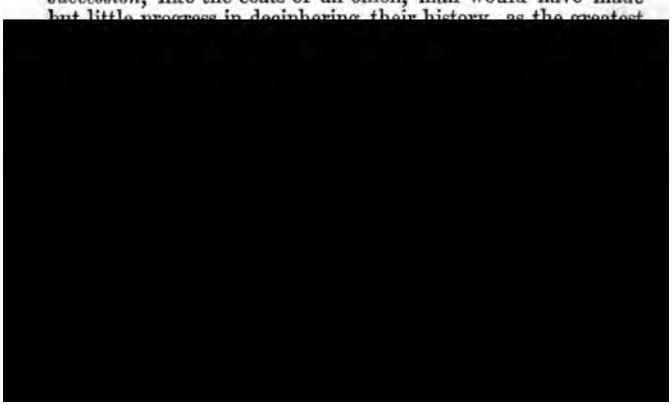
CHARACTERS OF ROCKS.—The student will readily learn to distinguish the *mechanical* characters of rocks, that is, that which relates to their external forms and internal texture. For example, he can have little difficulty in determining whether a rock be columnar or massive, granular or fibrous; he may, however, frequently be puzzled to decide as to its *mineral* composition. Certain simple minerals, as quartz, mica, iron pyrites, &c. are easily recognised; but in the majority of cases many tests are required, such as taste, smell, adhesion to the tongue, colour, lustre, form, hardness, and so on. For this purpose a knowledge of mineralogy is necessary; an acquirement which, at this stage, the student is not expected to possess. It will therefore be advisable that he familiarise himself with the most prevalent minerals and rocks by the inspection of actual specimens, cabinets of which can be obtained from the dealers for a trifling sum. To ascertain the precise *chemical* constitution of any rock, is a matter requiring considerable experience in the laboratory; but possessed of a retort and spirit-lamp, a blowpipe, a few test-tubes, and acids, the student may readily detect the presence of such substances as lime, iron, copper, lead, sulphur, soda, potash, &c.

MEANS OF GEOLOGICAL INVESTIGATION.

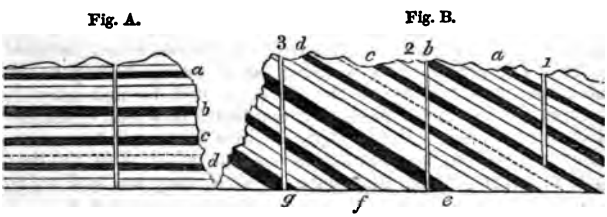
103. *The means placed within man's reach for investigating the history of the globe*, are of a very satisfactory description. The accessible crust being for the most part formed of stratified rocks occurring in definite order one above another, each composed of certain minerals, and containing different kinds of

fossil plants and animals, it enables us to determine the relative time required for the formation of certain strata, and to predict, from the kind of fossils, what must have been the state of the earth as to climate and other geographical features at the period when these remains were imbedded. Strata, for example, which contain the remains of marine shells and fishes, indicate that they have been deposited in seas; those containing fresh-water shells and plants, that they have been formed in lakes and estuaries; and as certain plants and animals now flourish in a tropical climate, so will similar fossil remains indicate that they have lived under a similar temperature. Fine-grained and thinly-laminated beds, such as clay-slate, must have been deposited under different conditions from a bed of gravelly conglomerate; and the circumstances which went to the formation of coal, must have been widely different from those under which chalk was formed. Further, some strata lie in a slanting position; and as we know that all matter deposited from water arranges itself in nearly horizontal beds, these strata must have been turned up by some elevating cause. No extensive elevation of the crust, however, can take place without causing rents and fractures, contortions, and other dislocations of the strata; and from the magnitude of these, some idea may be formed of the volcanic forces which caused them. Thus it is, by the stratified rocks, the order in which they occur, the kind of material of which they are composed, and the organic remains imbedded in them, that the geologist is enabled to proceed with his investigations.

104. *Had the stratified rocks lain in regular undisturbed succession*, like the coats of an onion, man would have made but little progress in deciphering their history, as the greatest



into the earth's crust, from the expense of working deep shafts, and the difficulty of carrying off their water. Were the same series of rocks, however, thrown up in a slanting position



(fig. B), then every shaft that pierced them would add to the amount of our information. For example, the shaft No. 1 pierces the coal-beds *a*, *b*, and *c*; No. 2 the coal-beds *c*, *d*, and *e*; and No. 3 the coal-beds *e*, *f*, and *g*. Now, by adding the results of these comparatively shallow shafts, they would furnish us with information respecting the whole series of strata from *a* to *g*, and which, in a horizontal position, human means never could have reached. By collecting and comparing the results of many shafts and borings, geologists are enabled to map out sections of extensive districts, and so become acquainted with the structure of the earth to enormous depths.

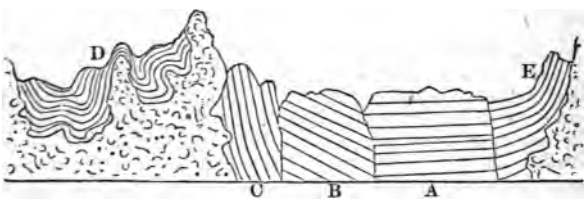
106. *The most extensive and satisfactory sections* of stratified rocks are those presented by ravines, and by the sea-shore. Thus, in tracing the course of a river, as represented by the following engraving, the geologist would become acquainted

with several series of rocks, and see their mineral and fossil characters much more distinctly than by any shaft or boring. Here the river bank exposes the strata from C to D in regular succession, where it is obvious, had they been in a horizontal position, only two or three beds would have been cut through by the action of the water. Such sections are numerous in hilly countries and along the sea-coast; and in these situations should the student make himself familiar not only with the succession of strata, but with the modes and peculiarities

of stratification, which can never be perfectly understood unless from actual observation.

FORMS OF STRATIFICATION.

107. *The stratified rocks* being, as it were, the key to the structure and history of the earth, it will be necessary to advert to some of the more common forms in which stratification is presented. When strata lie in a flat or level position, they are said to be *plane* or *horizontal*, as at *A* in the subjoined figure; when they slant, as at *B*, they are said to be



inclined, and the angle which they form with the horizon is called the *dip*, or angle of inclination; when highly inclined, as at *C*, they are termed *vertical*, or *edge* strata, as appearing to be set on edge; when bent and twisted, as at *D*, *contorted*; and when suddenly bent up by subterranean forces, as at *E*, they are said to be *tilted up*.

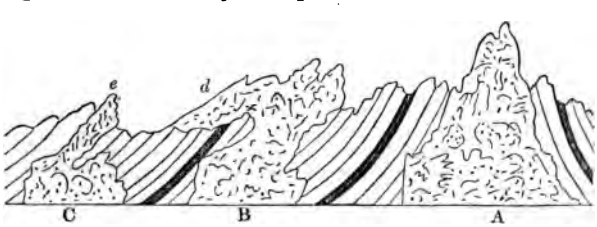
108. *Strata which dip in two opposite directions* from a common ridge, as at *a*, are said to form an *anticlinal axis*, or *saddle-*

parallel to each other; but *unconformable* when one set of beds overlie a lower series, without any conformity to the position of the latter. The strata at *x* are unconformable to those upon which they rest. There are several other terms applied to the position and inclination of stratified masses, but the above are those which most frequently occur.

POSITIONS OF UNSTRATIFIED ROCKS.

109. *As all stratified rocks were originally laid down in a position nearly horizontal,* the different inclinations and contortions described above must have been produced by elevating or igneous causes. Whether the upheaving forces exerted themselves through volcanic vents, accompanied by discharges of unstratified or igneous rock, or simply as earthquakes, they would produce other appearances than mere change of position in strata. These appearances are generally known by the name of *fractures*, or *disruptions*, and may or may not be accompanied by discharges of igneous rock.

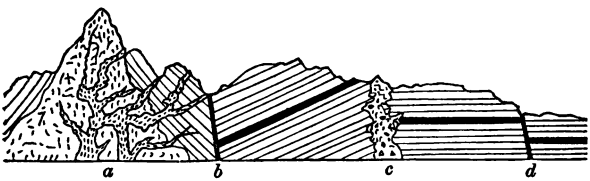
110. *Discharges of igneous rock* present themselves either as *disrupting*, *interstratified*, or *overlying* masses. In the accompanying section, *A* is simply a disrupting mass, or mountain range, by which the original strata are broken asunder; *B* is partly a disrupting mass, and partly overlying, as it overlies the strata at *d*; and *C* is both disrupting and interstratified, part of the fused mass appearing between the strata at *e*. Disrupting masses are caused by the expansive force of the fused mate-



rial from beneath; overlying masses by the rock spreading itself, when in a liquid state, over the surface of the strata; and interstratified by overlying masses being covered by a new deposition of strata. Sometimes there is a *pseudo* or *false interstratification;* that is, when the expansive force of the igneous rock has raised one set of strata from another, and inserted itself for some distance between them. In either case

the interstratified igneous rock presents no regularity or continuity of stratification, and is easily distinguished from rocks formed from sediment in water.

111. *Fractures of the strata* caused by subterranean forces are known by the terms veins, faults, dykes, slips, hitches, &c. In the subsequent figure, *a* is a suite of *veins* traversing unstratified and stratified rocks; *b* a *fault*, or *dislocation*, on each side of which the strata are thrown at different inclinations; *c* a *dyke*, composed either of igneous rock injected from below, or of clay and gravel washed in from above, also accompanied by an alteration of the dip; and *d* a *hitch* or



slip arising from a portion of the strata having been thrown down to a lower level without any change in the inclination. Of course the phrase *thrown down* is merely relative; for while the strata on the right of *d* appear to be thrown down, those on the left seem to be thrown up. The mining terms, *up-throw* and *down-throw*, therefore, refer to the same phenomenon, and are used according to the position from which the strata happen to be viewed.

ORYCTOLOGY—SCIENCE OF FOSSILS.

112. *Fossils, whether vegetable or animal, generally partake of the character of the rocky substances in which they are imbedded;* that is, if occurring in limestone, they will be more or less calcareous; if in coal, more or less bituminous; and so on of other substances. It must not be supposed, however, because a plant or animal is found in limestone, that it will be always wholly calcareous, or because it is found in coal, that it will be bituminous; the fact is, that fossils often present very irregular characters, the organic substance being sometimes entirely destroyed, leaving only its cast or impression. But whatever changes they have undergone, they may, for the sake of convenience, be arranged into three classes; namely, *petrifactions*, converted into stony matter; *bituminizations*, converted into bituminous matter; and *metallizations*, where the substance of the fossil, whether stony or bituminous, is pervaded by some metallic substance.

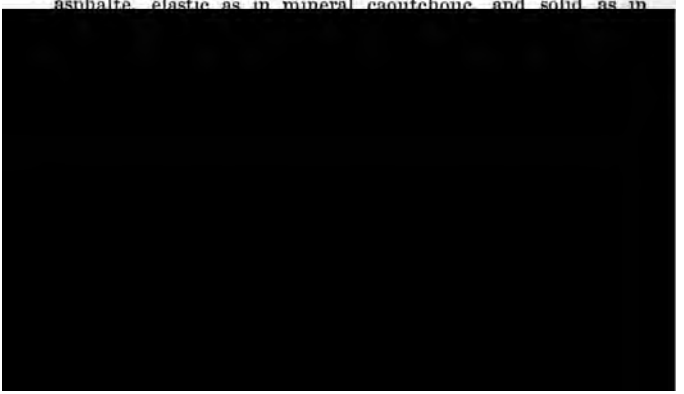
PETRIFACTION, BITUMINIZATION, AND METALLIZATION.

113. THE PROCESS OF PETRIFACTION consists in the infiltration of stony matter into the pores of bone or vegetables. In some instances, the animal or vegetable substance has been almost entirely dissolved, and the stony matter so gradually substituted, that the petrifaction presents a perfect resemblance in its minutest parts to the original structure. Petrifaction has been artificially attempted, by burying bones in mud, clay, and lime; when it was found that at the end of one year the bones had become harder and heavier, and scarcely distinguishable from true fossils. Springs containing lime in a state of chemical solution are familiar examples of petrifying agents, when they convert pieces of moss, straw, twigs, and other bodies, into limy or calcareous matter. Lime is one of the most prevalent petrifying agencies; but wood is often found converted into flint, or silicified; and many fossil trees are mere masses of fine-grained sand or quartz.

114. *The organic structure of plants and animals is not destroyed by petrifaction,* as has been proved by many experiments. For example, slices of fossil trees have been made so thin as to be semi-transparent, and thus show the traces of vegetable fibre; and fossil zoophytes have been suspended in acids till the whole of the lime was dissolved, leaving the animal tissue distinct in its original form, and sometimes

in its original colour. From this it will be perceived that the structure of the organism always more or less remains, and forms a basis for the petrifying solution which thoroughly pervades it, without disturbing the arrangement of those parts on which its characteristic form depends. It is this form or external character which enables geologists to compare and classify fossils with existing plants and animals.

115. *Bituminization* is that process by which vegetables insensibly lose their organic structure, and pass by a chemical process into bitumens; that is, into inflammable substances, of which coal, mineral pitch, asphalte, &c. are examples. Bituminization may sometimes be regarded as a sort of petrifaction, as when substances not originally vegetable are impregnated with bituminous matter, such as fossil fishes found in bituminous slate. But bituminization proper is totally different, and refers only to a certain change which vegetables undergo, by which they more or less lose their vegetable texture, and are converted into solid or liquid bitumen. To render this more evident by analogy:—If a piece of animal muscle be buried in the earth, where it obtains sufficient moisture and warmth, and is wholly excluded from the air, it is soon changed into a fatty wax-like mass (called *adipocere*, from the Latin, *adeps*, fat, and *cera*, wax), in which no trace of animal fibre is present. In like manner, if vegetable matter be excluded from the air, and subjected to heat and moisture, it is gradually converted into a black viscous and inflammable substance, called *bitumen*. This bitumen is found in all states of purity: pure and limpid as naphtha, oily as petroleum, viscous or slaggy as in mineral pitch or asphalte, elastic as in mineral caoutchouc, and solid as in



is obtained. This process of bituminization has been defined as "a fermentation peculiar to vegetable matter placed in such situations as not only to exclude the external air, and secure the presence of moisture, but prevent the escape of the more volatile principles." Every one is familiar with the kind of fermentation which takes place when half-dried hay is thrown into a heap; it gives off heat, becomes black in colour, and frequently takes fire and is consumed. It is this heating process which produces the bituminous fermentation when the vegetable mass is excluded from the air, and subjected to moisture and pressure. Animal remains may be impregnated with bitumen; but it is vegetables alone which can be converted into mineral pitch, jet, and common coal; and these substances are more or less pure, according as earthy matter may be mingled with them.

117. *Metallization* is that process by which fossil remains become impregnated with, or wholly converted into, metallic substances. The student must be aware that metals can be dissolved or held in a state of solution, as well as in a state of fusion. In this state of solution they are borne about by the waters which hold them; and these waters either percolate through the earth, or mingle intimately with the substances which compose it. The strata which imbed fossils generally contain metallic substances, such as iron; animals and vegetables, when in a state of decay, give off certain gases; water is always present in greater or less abundance; and thus the metallic substances, the gases and water, by chemical union, form compounds, which enter thoroughly into the pores of the fossils, and so convert them into a metallic, instead of stony or bituminous state. The changes thus effected are sometimes partial, the external parts of the fossil being metallised, whilst the interior remains stony or bituminous; sometimes the fossil is simply covered over with an incrustation of metallic salts, such as iron pyrites; at other times the original elements of the fossil remain thoroughly imbued with the metal; while not unfrequently the whole substance is rendered metallic, every trace of organic structure being obliterated.

118. *By these three processes—Petrifaction, Bituminization, and Metallization*—have the remains of plants and animals, which once lived and grew on the face of the globe, been preserved in the strata which compose its crust. So complete in many cases is this system of preservation, that the geologist is enabled not only to discover their form and structure, but to decide with certainty as to their habits, and to say whether they were fresh-water or marine, whether terrestrial or

aquatic, whether they lived and flourished under a tropical or under a temperate climate.

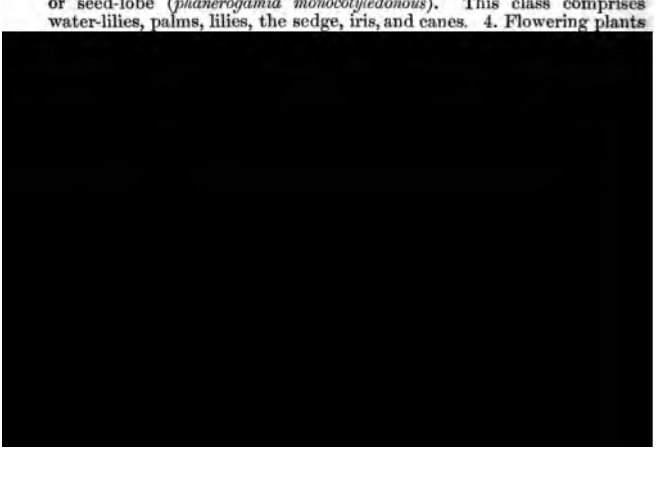
FOSSIL BOTANY AND ZOOLOGY.

119. Before the geologist be qualified to decide as to the nature of fossil plants and animals; before he can classify them and compare them with those now existing, or determine all the conditions under which they must have flourished, he would require to be acquainted with the leading facts of botany and zoology. In an elementary work of this kind, it would be out of place to enter largely into the characteristics of these sciences; but as a certain amount of knowledge is necessary to the understanding of subsequent details, we may shortly recapitulate the classification of plants and animals as generally received among botanists and zoologists.

120. VEGETABLES may be arranged under two grand divisions—CELLULAR and VASCULAR:—

I. *Cellular*—without regular vessels, but composed of fibres which sometimes cross and interlace each other. Confervæ, lichens, fungi, algæ (sea-weeds), and mosses, belong to this division. In some of these families there are no apparent seed organs.

II. *Vascular*—with vessels which form organs of nutrition and reproduction. According to the arrangement of these organs, vascular plants have been divided into four classes:—1. Without perfect flowers, and with no visible seed organs (*cryptogamia*). To this class many fossil plants belong; such as gigantic tree ferns, horse tails, and others resembling ferns. 2. With flowers, but having the seeds naked (*phanerogamia gymnospermous*). To this class belong the cycadeæ, or pine apple tribe, and the coniferæ, or firs. 3. Flowering plants with one cotyledon or seed-lobe (*phanerogamia monocotyledonous*). This class comprises water-lilies, palms, lilies, the sedge, iris, and canes. 4. Flowering plants



circulation, and particular organs for breathing by. Animals with Bivalve, Univalve, and Chambered shells, belong to this division; though many molluscs, like the common snail, have no shell.

III. *Articulated*—to this division belong Worms, Crustaceous animals like the lobster, and all Insects. Their nervous system consists of two long cords, ranging along the body, and swelling out in different parts into knots or ganglions. Worms having their bodies composed of rings are called annelides, and have red blood: some species of worms inhabit a calcareous tube, supposed to be formed by exudation.

IV. *Radiated*—comprises all those animals formerly called Zoophytes, or animal-plants, as corallines, &c. In animals of this division, the organs of sense and motion are circularly disposed around a centre or axis; hence the term radiated, or disposed in rays. They have no distinctly-marked nervous system, and the traces of circulation in many species can hardly be discerned. Many of the *radiata* are fixed, such as the corals; others move and float about, as the star-fish and sea-urchin.

122. *Besides the above distinctions*, which depend on the structure and form of plants and animals, there are others which should constantly be kept in view; namely, those depending upon mode of life, climate, and situation. The plants of the tropics are very unlike those of polar regions, both in number, size, and character; marine plants and animals are essentially different from those inhabiting fresh waters; and aquatic plants and amphibious animals present a very different appearance from those constantly existing upon dry land. Each race of plants and animals is, moreover, perfectly adapted for the functions it has to perform in the economy of nature; and is furnished with peculiar organs, according to the kind of food upon which it lives, and the other habits it displays. Thus, one set of organs indicates swiftness, another strength, a third prehensile or seizing powers, a fourth climbing, leaping, or swimming powers, a fifth that the animal lives on roots, on herbage, or on the flesh of others.

123. *As in the vegetable and animal economy of the present day, so in all times past;* and thus the geologist, by analogy and comparison, is able to decide as to the character of the fossil plants and animals which he discovers. He finds in their characters and skeletons a key to the modes of their existence, and can tell with precision whether they lived in the waters or on dry land, in fresh or in salt water, in a cold or in a hot climate; whether animals browsed upon plants or lived upon other animals, whether they are furnished with organs indicating an amphibious existence; and in general can determine their character and modes of existence. Moreover, as certain classes of plants and animals indicate certain conditions of the world, the geologist will be enabled by their remains to decipher the past history of our

globe, and so arrive at that which is the aim and object of all true geological research.

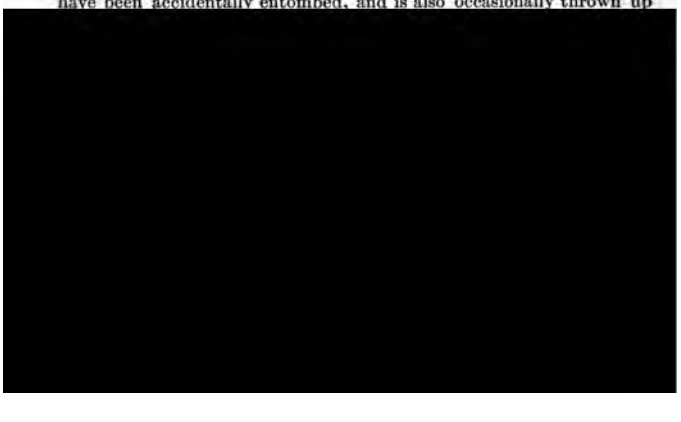
EXPLANATORY NOTE.

PETRIFACTIONS are, in general, described according to the mineral substance which enters most abundantly into their composition. If it be lime, then they are designated *calcareous* (Lat., *calx*, lime) ; if flint, *siliceous* or *silicified* (*silex*, flint) ; and so on of other minerals.

BITUMEN (Gr., *pitus*, the pitch tree)—a variety of inflammable mineral substances, which, like pitch, burn with flame in the open air. Naphtha, petroleum, and asphaltum, are familiar examples ; and all substances impregnated with these bitumens are said to be *bituminous*. As mentioned in the text, it is the prevalent opinion that all bituminous matter is of organic or vegetable origin.

BITUMINOUS FERMENTATION.—All vegetable matter is liable to certain states of fermentation, according to the degree of heat, air, and moisture to which it is subjected. These states have been successively described as the saccharine, vinous, acetous, septic, and bituminous. For example, the *saccharine* is that which manifests itself in the operation of malting and in the ripening of fruits ; if water and heat be applied, it passes into the *vinous*, or that by which wine and spirituous liquors are formed. Again, if, while the vinous is going on, air be partially admitted, the *acetous*, or vinegar-forming fermentation, will be produced ; and by further exposure of the vegetable matter to the air, it will pass into a mass of earth and carbon : this fits it for the *septic*, or putrefying process ; but if air be excluded, and heat, moisture, and pressure be present, the *bituminous* will be the result. By a knowledge of these processes, it is easy to understand how malt, wine, vinegar, vegetable mould, and coal, are respectively formed.

ADIPOCERE (Lat., *adeps*, fat, *cera*, wax)—a fatty substance produced by the decomposition of the flesh of animals in moist situations, or under water, resembling, in some of its properties, a mixture of fat and wax. It is found in damp grave-yards, in peat-bogs where animals have been accidentally entombed, and is also occasionally thrown up



characters stamped upon the rocks which constitute its crust —characters obviously analogous to such as are now produced by causes in active operation around us. It was necessary, therefore, to learn something of the existing structure and conditions of the globe, and of the causes—mechanical, chemical, and vital—which are modifying these conditions, in order that we might be enabled to reason from what is recent and apparent, to that which has taken place at more remote periods.

125. *The term rock is applied by geologists* not only to those hard substances usually called so, but also to all sands, clays, gravels, and marls which occur in beds, strata, or masses. It is also used to denote a collection of such substances: thus, we say the "rocks of a country;" or, speaking more definitely of any mineral series, we say the Chalk rocks, the Carboniferous rocks, and so on. The rocks which compose the crust of the earth, though varying much in mineral character, as well as external appearance, occur either in masses, or in series having a close resemblance to each other; so much so, that geologists conclude that certain series have been formed under similar circumstances. This opinion is further confirmed by the fact, that certain series of strata always imbed fossils of a different character from those contained in any other series; hence the origin of rock classification.

126. *Leibnitz, in* 1680, *divided rocks into two great classes*—STRATIFIED and UNSTRATIFIED—the latter being the result of igneous fusion, and the former that of aqueous solution. This distinction, though of importance at the period to which we refer, was still of little avail in deciphering the history of the earth, as unstratified rocks are mingled with the highest as well as with the lowest strata; and as, moreover, the stratified rocks differ essentially from each other, and often contain very different fossil remains. Lehman, a German mineralogist, next proposed to divide the stratified rocks into—

PRIMITIVE—those containing no fossil organic remains.
SECONDARY—those containing remains of animals and vegetables.
LOCAL—those but partially occurring in different districts.

127. *Werner, the great German geologist, improved upon this classification,* and divided all rocks into Primary, Transition, Secondary, and Local. The term *Transition* was added by Werner, as implying that the rocks so called exhibited a passage from the primary into the secondary in regard to their mineral character, and also that the earth was changing from an uninhabitable to an inhabitable state during the period of their formation. Subsequently, from the fossil discoveries of Cuvier and others, a more definite idea was attached to the term Local, and the word Tertiary was

employed to denote all those regularly stratified beds which occur above the Chalk strata. These divisions—Primary, Transition, Secondary, and Tertiary—though liable to many objections, are still more or less in use by geologists; hence the following classification of the stratified rocks which compose the crust of the earth :—

FORMATIONS.

SUPERFICIAL ACCUMULATIONS—all loose and irregularly deposited masses of clay, sand, gravel, and boulder stones.

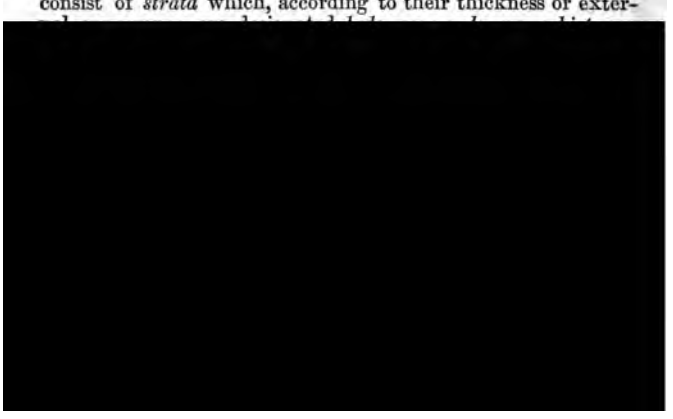
TERTIARY—local deposits of regular strata, containing remains of plants and animals, not differing widely from those now inhabiting the globe.

SECONDARY—strata of chalk, clay, and shale, red and white sandstones, coal, ironstone, and limestone—occurring in many parts of the world, and containing fossil plants and animals of different species from those now existing.

TRANSITION—strata of sandstones, shales, slates, and limestones—containing few or no fossil plants, and the remains of no higher animals than crustácea, shell-fish, corals, and corallines.

PRIMARY—slaty and crystalline strata, very hard and compact, and totally void of organic remains.

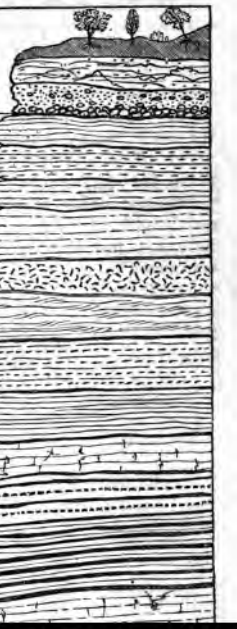
128. *As geologists became better acquainted with the succession of the stratified rocks, a more minute subdivision took place,* and these formations have been found to consist of systems, series, and groups of strata differing considerably from each other. Thus the term *formation* is applied to designate strata which seem to have been formed under nearly similar circumstances. A formation may consist of several *systems*—that is, strata having nearly the same mineral and fossil character; and there may be several *groups* in a system, such as a sandstone or limestone group. All these groups consist of *strata* which, according to their thickness or exter-



SECONDARY FORMATION.	*Chalk System.*	CHALK—soft and white, with layers of flint; chalk, hard, and without flints.
		GAULT, or beds of bluish marly clays, with green sand.
		GREEN-SAND—beds of green ferruginous sands, with chert nodules.
	Oolitic System.	WEALDEN GROUP—beds of clay, argillaceous limestones, and sands.
		OOLITE—beds of oolite limestone, calcareous grits, sands, and clays, all calcareous.
		LIAS GROUP—bluish clays, alum shales, marls, and limestones, all finely stratified.
	New Red Sandstone, or Saliferous System.	SALIFEROUS MARLS—variegated shales and shell limestone, with bands of sandstone.
		RED SANDSTONE GROUP—fine-grained, sometimes conglomerate.
		MAGNESIAN LIMESTONE—thick-bedded limestones and calcareous conglomerates.
	Carboniferous System.	COAL MEASURES—alternating beds of coal, shale, ironstone, and sandstone.
		CARBONIFEROUS, OR MOUNTAIN LIMESTONE—thick-bedded grayish limestones and shales.
		CALCIFEROUS SANDSTONES — white, thick-bedded sandstones, and calcareous shales.
	Old Red Sandstone System.	YELLOW SANDSTONES, with beds of mottled shales and marls.
		RED SANDSTONES—sometimes fine-grained, sometimes quartzose and conglomerate.
		GRAY OR RUSTY-COLOURED SANDSTONES—micaceous, and often in flags or thin-bedded.
TRANSITION.	*Silurian System.*	UPPER SILURIAN rocks—gray and bluish limestones, with coloured micaceous shales.
		LOWER SILURIAN rocks—impure shelly limestone, mottled sandstones, dark calcareous flags.
	Grauwacke System.	HARD ARGILLACEOUS rocks—thick-bedded sandstones, slaty sandstones, and limestones.
		FINE AND COARSE-GRAINED slaty rocks—gray micaceous slates.
PRIMARY.	*Clay-Slate System.*	CLAY-SLATE—finely laminated; dark, liver, and purplish-coloured.
		HORNBLENDE AND CHIASTOLITE slates, finely laminated.
	Mica Schist System.	CHLORITE SLATES—greenish-coloured slates, with mica, mica schist, talc schist, crystalline limestone, and quartz rock.
	Gneiss System.	GNEISS ROCKS—intermingled with irregular beds of quartz rock, crystalline limestone, and mica schist.

To assist the student in forming an idea of the succession of these formations and systems, the stratified rocks are more summarily arranged in the following diagram :—

I Modern Epoch
II. Tertiary =
III. Secondary = Cretaceous, Wealden, Jurassic or Oolitic, Trias?
IV. Palæozoic = Permian, Carboniferous
V. Hypogene Rocks Devonian, Silurian, Cumbrian (See below)



TERTIARY.

Vegetable Soil.
Alluvial Clay, Sand, and Gravel.
Diluvial Clay with Boulders.

Sandstone and Calcareous Grits.
Estuary Marls, Limestones, &c.
Blue and Plastic Clays, Marls, &c.

SECONDARY FORMATION.

Chalk Beds and Green-sand.
Oolite Limestones and Grits.
Lias Limestone and Shales.
Saliferous Marls, Shell Limestone.
New Red Sandstone.
Magnesian Limestone. Composed of Carbonate of Lime & do of Magnesia & a
Coal Beds alternating with Sandstones, Clay-shale, Ironstone, and impure Limestones.
Mountain Limestone.

a * In England a rock is generally of a yellowish colour but sometimes passing from the earthy form to a compact white stone of great hardness. —

129. *The unstratified or igneous rocks occur in no regular succession*, but appear amidst the stratified without order or arrangement; heaving them out of their original horizontal positions, breaking up through them in volcanic masses, and sometimes overrunning them after the manner of liquid lava. From these circumstances, they are in general better known by their mineral composition than by their order of occurrence. Still, it may be convenient to divide them into three great classes; *granitic*, *trappean*, and *volcanic* —granitic being the basis of all known rocks, and occurring along with the primary and transition strata; the trappean of a darker and less crystalline structure than the granitic, and occurring along with the secondary and tertiary rocks; and the volcanic still less crystalline and compact, and of comparatively recent origin, or still in process of formation. Classifying the stratified and unstratified rocks after this idea, they would present the following tabular arrangement:—

Unstratified.	*Associated with,*
VOLCANIC.	SUPERFICIAL ACCUMULATIONS—soil, alluvium, diluvium.
TRAPPEAN.	TERTIARY—crag, fresh-water marls, London and plastic clay. SECONDARY—chalk, oolite, lias, new red sandstone, coal measures, mountain limestone, old red sandstone.
GRANITIC.	TRANSITION—silurian and grauwacke rocks, concretionary limestones. PRIMARY—clay-slate, crystalline limestone, mica schist, quartz, and gneiss rocks.

This division of the igneous unstratified rocks subserves many useful purposes in geology; at the same time that it is a distinction warranted by the nature, aggregation, and aspect of their component minerals. The *granitic*, so named from their distinctly granular and crystalline texture, comprise granite, syenite, protogine, primitive greenstone, serpentine, porphyritic, and other varieties of granite. The *trappean* (Swedish, "trappa," a stair) are so called from the step-like or terraced sides of the hills formed by these rocks, which include basalt, greenstone, clinkstone, claystone, trachyte, porphyry, and amygdaloid. The *volcanic*, as the name implies, are those products discharged by recent or active volcanoes, such as lava, obsidian, scoriæ, pumice, and tufa. As associated in the crust of the earth, the Unstratified and Stratified rocks would present something like the annexed section:—

erupted from ancient volcanoes

II. Lava, Scoriæ, Pumice?, Ashes &c.

OF EXISTING ARRANGEMENT OF ROCKS.

Transition. *Primary.*

ondary.

Rocks appear in hills and irregular disrupting masses, from the older granite to the
in their regular order of succession. The *Primary* slope from the side of a lofty
nt or contorted strata; the *Transition* lie between the ranges of less elevated moun-
ed position, the Mountain Limestone being raised up on the hill-side, with the Coal
oken up by faults, and the Magnesian Limestone and Chalk rising up into slight
a; and the *Superficial Accumulations* occur either as sandy downs by the sea-shore,
rlier formations. The student will perceive how the Tertiary strata are said to be
verlie them; and how the Coal Beds are above the Transition rocks, though removed
The lowest strata being formed first, he will also understand why coal is said to
alk younger than coal.

130. *It must not be supposed, however, that the stratified rocks always occur* in any portion of the earth's crust in full and complete succession, as represented above; all that is meant is, that such would be their order if every group and formation were present. But whatever number of groups may be present, they never happen out of their regular order of succession; that is, clay-slate never occurs above coal, nor coal above chalk. Thus at London, tertiary strata occupy the surface; in Durham, magnesian limestone; in Fife, the coal measures; and in Perthshire, the old red-stone and clay-slate; so that it would be fruitless to dig for chalk in Durham, for magnesian limestone in Fife, or for coal in Perthshire. It would not be absurd, however, to dig for coal in Durham, because that mineral underlies the magnesian limestone; or for old red sandstone in Fife, because that formation might be naturally expected to occur under the coal strata of that county, in the regular order of succession. To make this order of succession still plainer, suppose the rock systems to be represented by series of figures, we might have—

7		7		7		7		5		7		3		5		6			
6		6		5		–		3		3		–		6		–			
5		5		–		–		2		–		5		–		2			
4	or	–	or	–	; but we never find	–	or	1	or any such inversion.
3		3		–		3		–		–		1		–		3			
2		–		3		2						2				–			
1		1		2												1			

Any member of the series may be absent; but those that remain never occur out of their natural order of *supraposition*.

EXPLANATORY NOTE.

CLASSIFICATION OF ROCKS.—Other "Systems of Classification" than the above have from time to time been advanced by geologists; but as most of them are founded upon some favourite theory, or upon mere local data, they have not met with anything like a general reception. It may be necessary, however, to notice some of the distinctions which occur in the works of certain modern authors. Conybeare and Phillips, in their Geology of England and Wales, divide the stratified crust into the following orders:—

1. *Superior*—containing the Tertiary deposits.
2. *Supermedial*—comprising the chalk, oolite, and new red sandstone.
3. *Medial*—comprising the coal measures, mountain limestone, and old red sandstone.
4. *Submedial*—containing the Transition strata.
5. *Inferior*—embracing all the Primitive formations.

Others have proposed to divide the crust into five great formations; namely, *Colluvial*, *Cretaceous*, *Carboniferous*, *Schistose*, and *Crystalline*; each of these formations being subdivided into three systems. Sub-

divided in this manner, the carboniferous and cretaceous would present the following arrangement :—

Supercretaceous—plastic clays, marls, and lignite beds (Tertiary).
Cretaceous—chalk, chalk marls, and green-sand.
Subcretaceous—weald, oolite, and lias strata.

Supercarboniferous—variegated marls, red sandstone, and magnesian limestone.
Carboniferous—coal measures, millstone grit, and mountain limestone.
Subcarboniferous—old red sandstone.

The rocks of the stratified crust, divided and subdivided in this manner, are easily remembered; the arrangement, moreover, being one which is warranted by actual observation. The term *fossiliferous* is commonly employed to denote all those formations in which fossils have been found; and *non-fossiliferous*, those, like the mica schist and gneiss, in which no organic remains have yet been discovered. *Metamorphic* is sometimes applied to those non-fossiliferous systems, implying that the strata have been so metamorphosed by heat, as to obliterate all traces of fossil exuviæ. Mr Lyell divides the Tertiary strata into four groups; namely, *Eocene*, *Meiocene*, *Pleiocene*, and *Pleistocene*; these terms indicating the approach which the imbedded fossils make to existing nature. For example, Eocene (Gr., *eos*, the dawn, and *kainos*, recent), indicates those strata in which the *dawn* or commencement of recent animals takes place; Meiocene (*meion*, less), less recent; Pleiocene (*pleion*, more), more recent; and Pleistocene (*pleiston*, most), most recent, or approaching nearly to existing orders. Instead of Stratified and Unstratified, or Sedimentary and Igneous, some geologists make use of the terms *Neptunian* and *Plutonic*—the former being derived from *Neptune*, the god of the sea or water, and the latter from *Pluto*, the god of fire.

GRANITIC BASIS OF PRIMARY STRATA.

this globe was in a fused state, as has been supposed by many philosophers, the granitic crust is such as would be formed by cooling down of the igneous matter. Cooling and contracting irregularly, it would assume an unequal surface; here forcing itself up into considerable heights, and there sinking into hollows; the highest granitic mountains bearing no greater proportion to the size of the globe, than the blisters and scoriæ on a smelting furnace do to the liquid mass upon which they are formed.

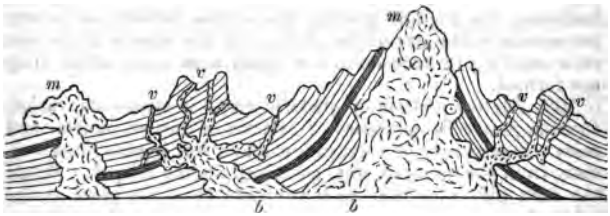
133. *The composition of granitic rocks* is somewhat varied. *Granite* proper is composed of crystals of felspar, quartz, and mica; is generally of a grayish colour; but is sometimes reddish, from the oxide of iron contained in the felspar. When the dark glistening mineral hornblende takes the place of the mica, the rock is known by the name of *Syenite*, from Syene in Egypt, where it is found in great abundance; and when talc supplants the mica, the admixture of felspar, quartz, and talc, forms the *Protogine* of French geologists. Sometimes it is formed by an admixture of quartz and hypersthene, with scattered crystals of mica, and is then called *hypersthenic granite;* or it may assume a speckled and mottled appearance, from the presence of variously-coloured minerals, such as chlorite, and is then called *serpentine*, from the fanciful resemblance it bears to the serpent's skin. *Porphyritic granite* is also of common occurrence; that is, when, in addition to the crystals which compose the general mass, larger crystals of felspar are indiscriminately mingled through it. Occasionally, the minerals in granite are so arranged as to bear a resemblance to the lines in Arabic writing; hence this variety is known by the name of *graphic granite.*

134. *Besides the above varieties*, there are other distinctions in use among geologists, according to the colour and composition of granitic rocks. Felspar, quartz, mica, hornblende, and hypersthene, are the most abundant constituents; but the aspect of the mass is sometimes modified by the partial admixture of other minerals, especially actynolite, chlorite, talc, schorl, and steatite. When only two minerals form a granitic rock (as felspar and mica), it is called a *binary granite;* when three (felspar, quartz, and mica), a *ternary granite*; and when four (quartz, mica, felspar, and hornblende), a *quaternary granite.*

135. *The structure of granite* is always massive and irregular; its texture is of various degrees of fineness, from a hard and close-grained rock, to a coarse and loose aggregation of primary crystals.

136. *The position and relation of granite* to the primary

strata is exceedingly irregular. Sometimes it rises up in mountain masses (*m m*), at other times spreads out as an undulating floor or basis (*b b*), and not unfrequently breaks through the unstratified rocks in veins (*v v v v v*) of the



Relative Positions of Granite.

most fantastic description. From these facts, there can be no doubt of its igneous origin; and the student will therefore be prepared to find it, like all other igneous rocks, occurring amid the stratified formations at various periods of the earth's history. Generally speaking, it is associated with the primary and transition formations, just as trap rocks are usually associated with secondary and tertiary strata, or as volcanic products are mingled up with the superficial accumulations now in progress; but the student is not on this account to suppose that granite may not also be found in conjunction with secondary or tertiary strata.

137. *The geographical distribution of granitic rocks* is very general; they form many of the most extensive mountain

products are applied are by no means unimportant. Compact granite, from its extreme hardness, is largely employed in the construction of docks, lighthouse foundations, bridges, and other structures where durability is the object in view. Waterloo Bridge in London, the Liverpool and other English docks, are built of Aberdeen granite. It is the ordinary building stone in the city of Aberdeen. The pyramids, Pompey's pillar, and other ancient Egyptian structures, are composed of it, as are also many monumental erections in our own country. Within these few years, the red granite of Peterhead, in Scotland, has been brought into use as an ornamental stone; and machinery has been erected to polish it like marble, to which many prefer it for chimney slabs, vases, pedestals, &c. Mica and talc are sometimes found in crystals more than a foot square; when of this size, they are split up into thin plates, and, from their transparency, used in some countries as a substitute for glass. Talc, by the Russians, is thought preferable to glass for ship light, as it is not apt to be broken by the firing of cannon; it also stands a higher degree of heat than glass without splintering. Some varieties of felspathic and talcose granites are easily decomposed by exposure to the atmosphere, and in this state produce a fine impalpable powder of silica and clay, of great use in the manufacture of porcelain, Mosaic tesseræ, buttons, and artificial gems. The clay from decomposed felspar is known in China by the name of *kaolin*, and is used by that nation in the manufacture of their finest china. According to Dr Boase, upwards of 12,000 tons of decomposed felspar (*Cornish clay*) are annually exported from Cornwall to the English potteries.

EXPLANATORY NOTE.

GRANITIC GROUP.—To the many varieties of this group Mr Lyell applies the term *hypogene rocks* (Gr., *hypo*, under, and *ginomai*, I am formed); that is, nether, or under-formed rocks. This term he employs to avoid any theory as to the origin of granite; but it has not been generally adopted, the prevalent belief being, as mentioned above, that granite is of igneous origin; that it has resulted from the gradual cooling down of the globe while in an incandescent state; and that it therefore forms a basis for all the stratified systems.

GNEISS AND MICA SCHIST SYSTEMS.

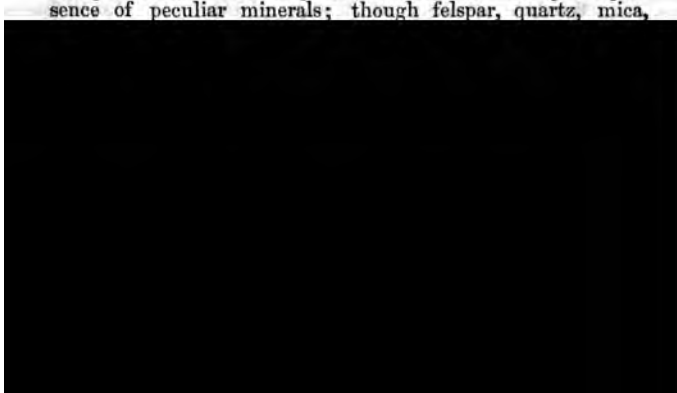
140. Before describing the primary rocks, it is necessary to advert to a general fact, applicable to the character of all stratified formations. *Siliceous*, *argillaceous*, *calcareous*, and

carboniferous compounds, may be said to constitute the solid crust of the globe; and these compounds differ in their appearance and mode of aggregation according to the order of their occurrence. For instance, the siliceous rocks of the primary strata are compact and crystalline; in the secondary they are less compact, lose their crystalline appearance, and become sandstones of various degrees of fineness; in the tertiary they are often so soft in their texture as to be called sands; while in the superficial they are merely loose accumulations of sand and gravel. So it is with the argillaceous rocks—from the compact and glistening clay-slates of the primary, through the slaty shales of the secondary, and the laminated clays of the tertiary rocks, up to the soft plastic clays of our alluvial valleys. As with the siliceous and argillaceous, so with calcareous and carboniferous; hence a table may be formed exhibiting these gradations:—

Siliceous.	*Argillaceous.*	*Calcareous.*	*Carboniferous.*
Sand,	Alluvial Clay,	Marl,	Peat,
Sandstone,	Laminated Clay,	Chalk,	Lignite,
Grauwacke,	Slaty Shale,	Limestone,	Brown Coal,
Quartz Rock.	Clay-Slate.	Crystalline Marble.	Common Coal.

Thus, as we descend into the crust, the mineral ingredients of the stratified rocks assume different degrees of aggregation, gradually becoming harder and more compact, till ultimately they present a crystalline texture scarcely distinguishable from the granitic basis.

141. *The composition of the primary strata*, like that of the granite on which they rest, is often modified by the presence of peculiar minerals; though felspar, quartz, mica,



Formation of Micaceous Sandstone/Examine/
Take a handful of quartzose sand mixed with mica/throw it
into a clear running stream/the materials are sorted by the

water/the grains of quartz fall directly to the bottom/while the
plates of mica (as a much larger size

and the abundance of fragmented mica gives its lamination a degree of parallelism not to be found in the former. Both, however, are frequently seen passing into each other, thus rendering it difficult to distinguish where the one system ends and the other begins. Passing over these dubious strata, the *mica schist system* is composed of alternations of mica schist, talcose schist, chlorite schist, hornblende schist, quartz rock, primitive or crystalline limestone, with occasional beds of clay-slate in the upper part of the system. Independently of their stratification, the mica schist rocks distinctly indicate, by their texture, that they have been formed by the action of water. The particles of which they are composed are more broken and rounded than those of gneiss—a circumstance arising from the fact, that they were partly derived from granite and partly from gneiss, which must thus have undergone a double process of attrition. The following engravings are intended to represent the external appearance of granite, gneiss, and mica schist—the first composed of distinct crystals, and showing no traces of lamination; the second irregularly laminated; and the third finely and regularly laminated.

Granite.

Gneiss.

Mica Schist.

143. *Gneiss and mica schist differ little from granite*, and still less from one another, in their mineral composition; showing clearly that it is chiefly in the degree of attrition which the original minerals have undergone, that their external differences consist:—

GRANITE—of felspar, quartz, and mica; felspar, quartz, hornblende; felspar and hornblende; or it may be of various combinations of these simple minerals.

GNEISS—of felspar, quartz, and mica; occasionally with hornblende and garnets in it.

MICA SCHIST—of mica and quartz, with hornblende and garnets contained in it.

TALCOSE SCHIST—of talc and quartz, and differs only in this respect from mica schist.

CHLORITE SCHIST—of chlorite and quartz.

HORNBLENDE SCHIST—of quartz and hornblende, occasionally with actynolite.

QUARTZ ROCK generally contains hornblende or mica irregularly imbedded in it.

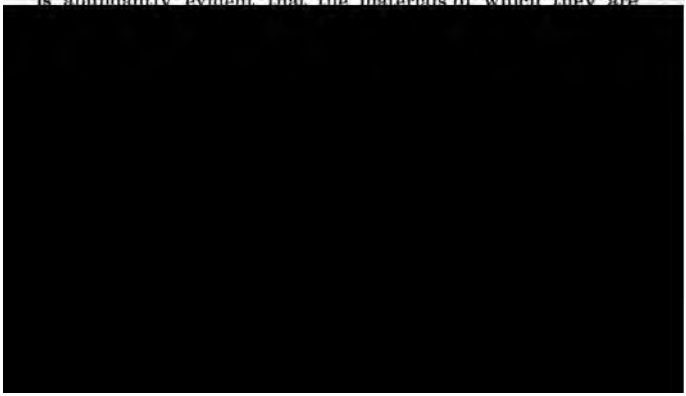
The particles of the primary strata are indefinite both as to size and arrangement—some are fine and close-grained, others

are conglomerate and coarse; but all bear evident traces of their aqueous origin.

144. *There is nothing like a regular order of succession* among the primary strata. It may be stated generally, however, that gneiss underlies the mica schist; that mica and other crystalline schists are the lowest in the system; and that quartz rock, primitive limestone, and clay schist, make their appearance towards the upper part of the series. Stratification is sometimes obscure, and not very persistent; that is, any one stratum is not found stretching over a great extent of country, as is the case with the secondary rocks. A seam of coal will often be found stretching over ten or twelve miles of country, without much difference either in quality or thickness; but in the primary systems, the strata thicken, thin out, and disappear in a very capricious manner. In absence of anything like a characteristic section, the following rocks may be mentioned as constituting the great bulk of the primary formation:—Gneiss, mica schist, talc schist, chlorite schist, shorlaceous schist, stea schist, hornblende schist, actynolite schist, quartz rock, crystalline limestone, hornstone, and protogine. Most of these rocks pass insensibly into each other, and thus many compounds are formed of which the student can only obtain a knowledge by the study of actual specimens.

145. *No organic remains have yet been discovered in the gneiss or mica schist systems;* and if life, either in a vegetable or animal form, existed at the time these rocks were deposited, it must have been exceedingly rare, and confined to a few limited points on the earth's surface. (See note, p. 80.)

146. *As to the origin of the gneiss and mica schist systems,* it is abundantly evident that the materials of which they are



agency, would assist in producing the crystalline texture; and thus a variety of schistose rocks might be formed at one and the same time. That a high temperature existed during the formation of the primary rocks, we have ample evidence, not only in their hard and crystalline texture, and in the absence of all organic remains, but in the occurrence of certain minerals, such as garnet, whose presence denotes that the rocks in which it is found have experienced a degree of heat sufficiently high to form such a fusible mineral, but not enough to melt the other constituents of which they are composed.

147. *The igneous rocks associated with the gneiss and mica schist systems* are, as may be anticipated, the granitic on which they rest, and from which their materials have been directly derived. Sometimes the granite is in immediate contact with the gneiss, so much so, as to render it matter of difficulty to say where the one ends and the other begins; at other times it touches the mica schist, or, it may be, passes through both in the form of dykes and veins. Later igneous rocks, such as porphyry, greenstone, and serpentine, are frequently found traversing the gneiss and mica schist in dykes and protruding masses; and occasionally, still more recent effusions of trap are found passing through the primary strata, with their associated dykes and veins of granite. Metalliferous veins are not of frequent occurrence in the primary strata of the British isles, though they are found in those of central and northern Europe. Thermal springs are perhaps still more rare, though abundant enough in the gneiss and mica schists of other countries.

148. *The extent of country occupied by the primary strata* is very great, although as yet but imperfectly ascertained. They occur abundantly in the Highlands and islands of Scotland, in the north of Ireland, along the flanks of the Pyrenees, the Alps, the great mountain chains of northern Europe, in Asia, in Ceylon, in Africa, and in America, particularly in the Brazils and the United States.

149. *The physical aspect of primitive districts* is bold, rugged, and unfertile. Thrown into lofty mountains by the granite, and into abrupt and vertical positions, it is chiefly among gneiss and mica schist that those deep glens and abrupt precipices occur which give the well-known picturesque effect to Highland scenery. The student will readily perceive how this effect is produced, when he considers the hardness of the rocks, and the highly vertical and contorted positions into which they are thrown; whereas in secondary formations, the position is in general flatter, and the strata

so soft, that they cannot present the same rugged and abrupt appearance.

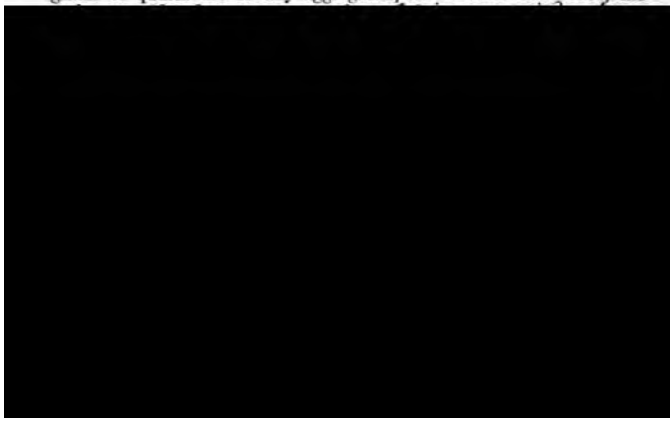
150. *The minerals of commerce derived from these systems* are by no means numerous. Several of the metallic ores, such as tin and copper, occur in veins traversing these strata. The limestones, from their highly crystalline texture, in general produce valuable marbles; but none of the other rocks are of use for architectural purposes. Potstone, or the *lapis ollaris* of the ancients, of which very pretty jars and vases are manufactured, is found in stea schist. Amianthus, or flexible asbestus, occurs among the mica schists, and is sometimes used in the manufacture of fabrics which are indestructible by fire. The garnet is a well-known precious stone; and many of the most valuable are found in the rocks of this system.

151. *It may be stated generally of gneiss and mica schist*, that they are the oldest sedimentary rocks, and rest upon masses which owe their origin to heat; that they are totally different from other stratified rocks, inasmuch as their particles have not undergone so much attrition, and likewise as they have been subjected to a higher degree of heat; that they are destitute of organic remains, and therefore afford no evidence of habitable dry land; and lastly, that they are spread over so great an extent, as to be considered almost universal.

In micaceous sandstones mica is abundant / it divides into thin silvery plates

EXPLANATORY NOTE.

SILICEOUS (Lat., *silex*, flint)—all rocks having a flinty texture are said to be siliceous. Quartz is the purest form in which silex occurs. When grains of quartz are loosely aggregated, as in some sandstones, the



rock—in other words, that it may be altered or metamorphosed sedimentary strata. By this theory all stratified systems may in time become metamorphic, so that geology can never hope to arrive at anything like a continuous history of the globe from its origin upwards—the older strata and their remains being thus successively obliterated. This theory, however, has not been generally adopted, and, from the plain evidences which most strata afford of their formation, it is not likely to be so.

CLAY-SLATE, GRAUWACKE, AND SILURIAN SYSTEMS.

152. It has been stated that the four great types of all stratified rocks are siliceous, argillaceous, calcareous, and carboniferous; and that, in general, each system is characterised by some prevailing type. The gneiss and mica schists have been described as eminently *siliceous*: we shall now learn that in the clay-slate, grauwacke, and silurian systems, *argillaceous* compounds prevail—almost wholly so in the first system, mingled with arenaceous strata in the second, and with calcareous and arenaceous beds in the third.

153. *The clay-slate system* presents a vast thickness of fine-grained fissile argillaceous rock, of considerable hardness, varying in colour, and of glistening aspect. The prevalent colours of slate are black, green, bluish, purplish, and mottled; some varieties being hard and splintery, others soft and perishable. The character of any particular slate is, however, very persistent; the accidental or imbedded minerals are few—these being chiefly cubic-iron pyrites, and crystals of chiastolite and hornblende.

154. *The composition of the grauwacke* is much more varied and irregular. As sandstone may be said to be consolidated sand, and conglomerate consolidated gravel, so may grauwacke be defined to be an aggregate of clay, grains of quartz, felspar, and mica, with fragments of jasper and other minerals. The cementing material is clay, which often constitutes the greater portion of the rock, and in such cases the texture differs little from that of clay-slate; but in many strata fragmentary ingredients prevail, so that the texture varies in fineness from that of a coarse slate to a conglomerate of pebbles more than an inch in diameter. Like clay-slate, grauwacke presents various degrees of hardness, though, generally speaking, it may be described as a highly indurated conglomerate—indicating most clearly its origin from the waste of earlier siliceous and argillaceous formations. Associated with the slates and grauwackes are occasional beds of concretionary limestone, which partake of the

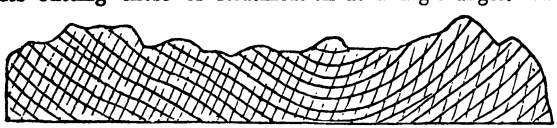
argillaceous character of the rocks with which they are associated.

155. *In the silurian system*, limestones occur more frequently, so that the calcareous type, or, at all events, an intimate blending of argillaceous and calcareous compounds, may be said to prevail. Until, a recent period, this system was considered as a portion of the grauwacke group, and as marking its passage into the gray micaceous beds of the old red sandstone. Merely looking at cabinet specimens, it would be impossible to distinguish between many of the grauwacke and silurian rocks, but taking them in the mass, they are readily distinguishable. In the first place, their sedimentary character is very marked; they present more rapid alternations from one kind of strata to another; they have undergone fewer changes by heat; and are generally looser and more earthy in their texture. The limestones are less crystalline than those of the early grauwackes; the arenaceous beds are also less siliceous, and more closely resemble ordinary sandstones, while the abundance of organic remains justifies their arrangement into a separate system.

156. *From this description of these systems*, it will be seen that their main type is argillaceous; eminently so in the clay-slates; abundantly enough in the grauwackes, which pass, in texture, from slate to a coarse quartzose conglomerate; and perceptibly in the silurian limestones, which are all of a dark argillaceous character. It is also worthy of notice, that the crystalline aspect which characterised the Primary Rocks disappears with the clay-slates, and gradually passes into an earthy or arenaceous texture in the grauwacke and silurian. It is true that some of the lower slates have a glistening

ture very distinctly marked in the clay-slates; it is only in the grauwacke and silurian that this is decided. *Lamination* may be said to prevail in the rocks of fine texture, and *stratification* in those of an arenaceous or calcareous character. The laminated structure of grauwacke is, however, of a different character from lamination in clay-slate; in the former it is the result of deposition, in the latter it is the effect of a subsequent change which the rock has undergone, called *cleavage.*

158. *Cleavage* differs from ordinary lamination in this respect, that it causes clay-slate to split up into thin plates *at right angles, or nearly so, to the bed of stratification;* while lamination simply implies that any stratum can be split up into a number of thinner layers or laminæ. Cleavage occurs in several varieties of rock, but it is most regular and distinct in clay-slate; and it is owing to this structure that the rock has the property of being split up into thin divisions for roofing and other purposes. The appearance which cleavage presents in the mass is represented beneath, by the nearly perpendicular lines cutting those of stratification at a high angle. How



Section Exhibiting Lines of Cleavage.

cleavage has been produced, is still an undecided problem among geologists; though it may be stated generally, that it seems to have taken place long after the deposition of the strata in which it occurs, and, like crystallisation, to owe its origin to the influence either of heat or of electricity, or perhaps to both. (See note.)

159. *The succession of strata in the clay-slate, grauwacke, and silurian systems,* has not yet been very clearly ascertained. In general terms, it may be stated that the lower slates partake of a micaceous or hornblendic character; that they become less crystalline as we ascend in the series, and are succeeded by finely-laminated grauwacke, with interstratified limestones. In the grauwacke there is no apparent order of succession, although, in most localities, limestones and argillaceous beds prevail in the lower, and grits and conglomerates in the upper portion of the system. In the silurian, order is still less obvious; but, on closer study, it is found that grits and grauwacke-looking rocks prevail in the lower portion of the system, dark-coloured shales and limestones in the middle, and slaty micaceous sandstones in the upper. The fol-

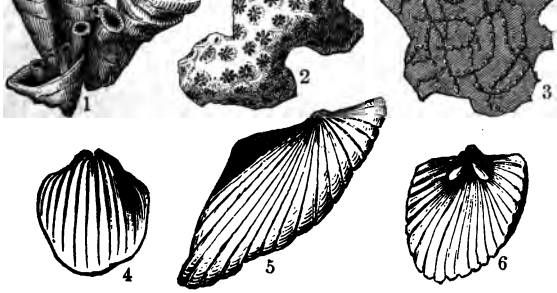
lowing detailed section will convey to the student a more correct idea of the order and succession among these systems :—

SILURIAN.	1. Slightly micaceous thin-bedded sandstones. 2. Gray and blue argillaceous limestones. 3. Liver-coloured shale, with concretions of earthy limestone. 4. Highly concretionary subcrystalline blue and gray limestone. 5. Dark-gray argillaceous shale, with nodules of earthy limestone. 6. Thin-bedded impure limestone, containing shells, alternating with finely-laminated micaceous sandstone of a greenish colour.
GRAUWACKE.	7. Sandstones, grits, and limestones ; arenaceous beds prevailing. 8. Dark-coloured flags, chiefly calcareous ; sandstones and sandy schists. 9. Grauwacke slates and sandstones, coarse limestones, and thick-bedded grauwacke rocks. 10. Dark argillaceous limestone, with shells and corals. 11. Peculiar slaty and flaggy beds : mottled in colour ; sometimes coarse and conglomerate, generally of moderate fineness, alternating with coloured clayey beds.
CLAY-SLATE.	12. An immense thickness of clay-slate of various colours—blue, black, greenish, purple, or mottled ; of fine grain, sometimes compact, sometimes soft and useless.

160. *The organic remains of these systems* are possessed of more than ordinary interest, from the fact of their being the earliest forms of life with which we are acquainted. In the preceding systems we have no traces either of vegetable or of

obliterated by the agency of heat, geological science has not been able to determine; but at present, we are warranted in stating, that only a few rare corals and shells occur in the clay-slate system; a greater number of corals, shells, and crustacea in the grauwacke; and a variety of corals, shells, crustacea, fish bones, and teeth, in the silurian.* So far as they have been examined, all these remains belong to species long since extinct; indeed, are distinct from those which occur in the Secondary Strata, and bear only a generic resemblance (often a faint one) to existing races.

161. *From the scantiness and peculiarity of organic life*, it is difficult to arrive at any conclusion as to the condition of the world at this early period. The existence of shell-fish would seem to indicate the co-existence of marine plants upon which they fed; and though we are aware that molluscous animals might prey upon each other, still, the probability is, that marine vegetation was to some extent spread over the bottom of the transition seas. The preponderance of coral-like animals points to a warm and favourable condition of the waters for their development; and it may be that this highly heated condition entirely prevented the growth of terrestrial plants, and rendered even those of marine growth of so rare occurrence. Be this as it may, we are only certain of several species of *Zoophytes*, *Mollusca*, and *Crustacea* in the clay-slate and grauwacke rocks—among which the most characteristic are those exhibited in the following group:—

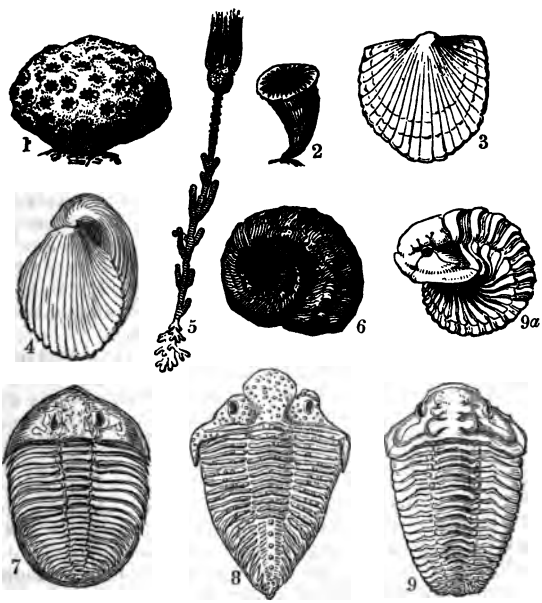


1. Cyathophyllum Cyathus; 2. Heliopora Porosa; 3. Catenipora Labyrinthica; 4. Producta; 5. Spirifera; 6. Terebratula.

162. *The fossils of the silurian system* are much more abundant; there are a greater number of species belonging to each genus; annulosa, crustacea, and fishes, are decided; and, according to many geologists, plants allied to the algæ (seaweeds), the equisetaceæ (horse-tails), filices (ferns), and others, make their appearance. Passing over the remains of plants and true vertebrated fishes, about the existence of which at this period there is still great obscurity, we shall notice some of the ascertained peculiarities of the radiata, mollusca, and articulata belonging to the Transition era.

163. *The waters of the silurian period* seem to have been crowded in some localities with zoophytes and corals, for certain limestones are as much composed of their remains as a coral reef is of recent corals. Among the radiata, the *crinoid* or *encrinite* family occur for the first time, these differing from other corals (see par. 300) in the self-dependent nature of their structure, their fixed articulated stalk, and floating stomach furnished with movable rays for the seizure and retention of their food. The shell-fish also become more numerous and distinct in form; *spiriferæ*, *terebratulæ*, and *productæ*, are every where abundant: and *chambered shells*, like the existing nautilus, begin to people the waters. It must be remarked, however, that the encrinites and chambered shells of this early period are not so numerous, so gigantic, or so perfect in their forms, as those of the Secondary Strata; it is in the mountain limestone group that the crinoidea attain their meridian, and in the lias and oolite that the *ammonites* and *nautili* are most fully developed. Of the crustacea of

the sides of each would have been useless, as it could only look across to meet the vision of the other; but on the inner sides there are no lenses, that nothing may, in accordance with a principle observable throughout nature, be thrown away. It is found that in the *serolis*, a surviving kindred genus, the eyes are constructed on exactly the same principle, except that they are not so high—a necessary difference, as



1. Astrea; 2. Turbinolia Fungites; 3. Terebratula Risca; 4. Leptæna Lata; 5. Actinocrinites; 6. Euomphalus Rugosus; 7. Asaphus de Buchii; 8. Asaphus Tuberculatus; 9. Calymene Blumenbachii; 9a. Side view of Calymene while rolled up.

the back of the serolis is lower, and presents less obstruction to the creature's vision. This little organ of a trivial little animal carries to living man the certain knowledge that, many ages ago, the air he breathes, and the light by which he sees, were the same as at this hour, and that the sea must have been in general as pure as it is now. If the water had been constantly turbid or chaotic, a creature des-

(turn over)

tined to live at the bottom of the sea would have had no use for such delicate visual organs. "With regard to the atmosphere," says Dr Buckland, "we infer that, had it differed materially from its actual condition, it might have so far affected the rays of light, that a corresponding difference from the eyes of existing crustaceans would have been found in the organs on which the impressions of such rays were then received. Regarding light itself also, we learn, from the resemblance of these most ancient organisations to existing eyes, that the mutual relations of light to the eye, and of the eye to light, were the same at the time when crustaceans endowed with the faculty of vision were placed at the bottom of the primeval seas, as at the present moment."

164. *The animals of this early period, like those now existing, were partly herbivorous* (*living on plants*), *and partly carnivorous* (*living on the flesh of others*). The polypes and crinoidea, it is true, merely secreted limy matter from the waters of the ocean wherewith to build their calcareous structures; but while certain tribes of shell-fish were living on the sea-weeds which flourished along the shores, other races were preying upon these, or upon each other. Among the vegetable eaters were the productæ, terebratulæ, &c.; the ammonites and trilobites were those which lived upon others.

165. *That the transition strata have been derived* partly from the disintegrated materials of the gneiss and mica schists, and partly from the granite, is abundantly obvious. In the gneiss and mica schists, the primitive crystals of the granite in many instances had undergone little attrition, and in most cases only

the silurian implies the agency of the coral animal, precisely similar to that now going forward in the Pacific. Here, then, we have a condition of the world with hills and valleys, rivers and seas—the atmospheric agents acting upon the cliffs and precipices; the aqueous also degrading the rocks, transporting the material, and depositing it along the shores of seas, whose waters gave birth to corals, shell-fish, and fishes. Fine clayey silt formed clay-slate; sand and other mud slaty sandstones; gravel grauwacke conglomerate; and coral polypes beds and reefs of limestone. We have no evidence of terrestrial life; and the necessary inference is, that the conditions of the world did not then permit of its being called into existence.

166. *The igneous rocks associated with the transition series* are granite, serpentine, porphyry, greenstone, varieties of trap, and mineral veins. Indeed there is scarcely a development of the clay-slate or grauwacke systems without associated granitic rocks; and the greater portion of the silurian strata are thrown into inclined and contorted positions by the same agency, while effusions of trap make their appearance among the latter strata. Perhaps the most extensive and gigantic efforts of volcanic power were exhibited at the close of this period; and there is abundant proof that all the principal mountain chains in the world were then upheaved. The Grampian and Welch ranges, the Pyrenees, Hartz mountains, Dofrafelds, Uralian, Himmaleh, Atlas range, Mountains of the Moon, and other African ridges, the Andes, and Alleghanies, all seem to have received their present elevation at the close of the transition period. From this fact, the student will more readily perceive how the primary and transition strata should be thrown into highly inclined and contorted positions; how they should be traversed by so many dykes and mineral veins; and how slaty cleavage, and other alterations by heat, should have taken place.

167. *The extent of country over which the clay-slate, grauwacke, and silurian systems are spread,* must be sufficiently indicated by the mention of the principal mountain ranges in the world, from whose sides and flanks their strata slope away for many leagues on either side.

168. *The geographical features of transition districts* are bold and mountainous, and are well illustrated by the characteristic scenery of Wales, the Cumberland Lakes, and the Scottish Highlands. "Supported by granite," says Professor Phillips, "and mixed with igneous masses, the slaty rocks of the English lakes rise to more than 3000 feet in height, and present a variety of outline, and intricacy of combination,

which, in connexion with clear lakes and considerable waterfalls, leave to Switzerland little superiority." This grandeur, intricacy, and variety of aspect can be readily accounted for, when we consider the height to which these strata have been elevated, the vertical positions into which they are thrown, and the irregularity of their composition, which allows them to be scooped out and worn down to a thousand forms—here craggy and splintery, there sinking, or rather cleft into fearful gorges and ravines.

169. *The economic uses* to which the minerals of these systems are applied are numerous and important. From the clay-slate are derived roofing-slate, writing-slate, and a variety of slates for ornamental and other purposes. Flagstones and pavement are obtained from the grauwacke and silurian beds, and several ornamental marbles from the limestone of the same systems. But the mere rock minerals are of little value in comparison with the metallic veins found in these strata. Tin, lead, copper, silver, gold, and other metals, are found abundantly in the veins which traverse the clay-slate; indeed they form in Britain, as well as in other countries, the principal metalliferous rocks, with the exception of the lead and ironstone, of the carboniferous system.

EXPLANATORY NOTE.

GRAUWACKE—a German miner's term, signifying *gray rock*; adopted in geology to designate the grayish slates and siliceous conglomerates of the transition strata. English geologists have conferred upon this group the name of *Cambrian*, from its forming a large portion of the

Grits—hard sandstone, in which the grains of quartz are sharp and angular, are technically called *grits*, as millstone-grit, grindstone-grit, &c.

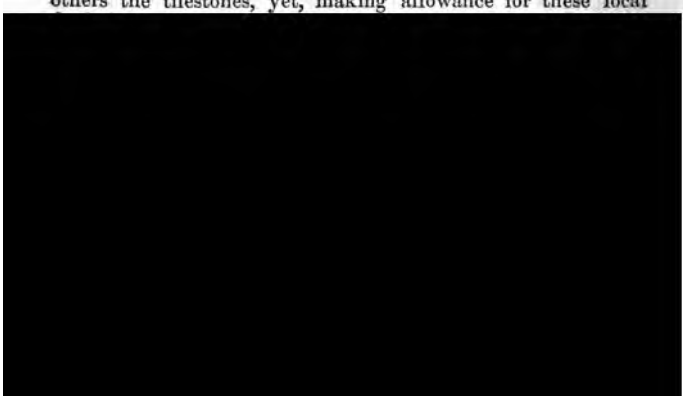
Cleavage.—The peculiarities of this structure have given rise to many speculations and experiments. Mr R. W. Fox submitted a mass of moist clay, worked up with acidulated water, to a weak *electric* action for several months; and it was found at the end of that time to present traces of cleavage, the laminæ being at right angles to the electric forces. Others are of opinion that cleavage is superinduced, when considerable *chemical* action takes place in any finely pulverised substance as clay—cleavage being thus regarded as a species of rude crystallisation. Another class of theorists, from observing that slaty cleavage occurs among the shales of the coal measures, when these are in the neighbourhood of igneous rocks, attribute the structure to *heat*. It is not unlikely that all these causes may have been concerned in producing cleavage; for, when better understood, it is more than probable that heat, electricity, and chemical action, are only modifications of one universal agency.

OLD RED SANDSTONE SYSTEM.

170. Until a comparatively recent period, geologists were accustomed to consider gneiss, mica schist, clay-slate, and old red sandstone, as sufficiently distinctive of all the stratified systems which lay underneath the coal measures. We have seen, however, that, in point of mineral composition, as well as in organic remains, the clay-slate differs essentially from the grauwacke; and that grauwacke, as we ascend, begins to lose its arenaceous character, and to be succeeded by a series of argillaceous and calcareous beds more prolific in fossils, and in the mass perceptibly different. To this series of strata Mr Murchison applied the term *Silurian system*—a system which may be said to partake of the character of the grauwacke beds beneath, as it insensibly passes into the gray micaceous flagstones of the old red sandstone above. The student must not, however, suppose that all these systems are to be met with fully developed in every country; all that the science of geology affirms is, that, when they are present, the above is their order of occurrence, and the general aspect and character they assume. Sometimes, indeed, the clay-slate is represented by a few indistinct argillaceous beds; and in many places it is difficult to discover anything like a well-defined series of strata corresponding to the silurian rocks of Mr Murchison; but, generally speaking, there is always some shade of distinction, either in mineral or fossil character, which enables us to trace the gradation of these successive systems. Whatever difficulty may be experienced in ascertaining the presence and limits of the grauwacke and silurian systems, there is seldom any doubt as to the old red sandstone, which, in the British islands, is one of the most clearly developed of rock formations.

171. *The composition of the old red sandstone*, as indicated by the name, is chiefly arenaceous, presenting a succession of sandstones alternating with subordinate layers of sandy shale. The sandstones pass, in fineness, from close-grained fissile flags to thick beds of conglomerate, the latter being composed of pebbles from the size of a hazel-nut to that of a man's head. The whole system is tinged with the peroxide of iron, the colours ranging from a dark rusty gray to brick-red, and from a mottled purple and fawn shade to a cream-yellow. The mottled aspect is principally found in the shales which, from their sandy character, may be regarded as imperfect sandstones. There are also some calcareous beds in the system, but these are not regularly developed, and are all siliceous and concretionary in their composition and texture. From their impure and concretionary aspect, they are generally known by the name of *cornstones*, and are of little or no use as limestones. Taken in the mass, the composition of this system is sufficiently indicated by the term *old red sandstone*—the epithet "old" being applied to distinguish it from another series of red sandstones which occurs above the coal measures, and is usually designated the *new red sandstone*.

172. *The order of succession among the old red sandstone strata* varies considerably in different localities. It has been stated that the prevailing mineral characters are—fine-grained red sandstones, including detached pebbles; beds of coarse conglomerate; fine-grained fissile micaceous beds of a gray colour, locally called tilestones and flagstones; layers of mottled shales; and strata of yellow sandstone. Now, although in some districts the conglomerate may be undermost, and in others the tilestones, yet, making allowance for these local



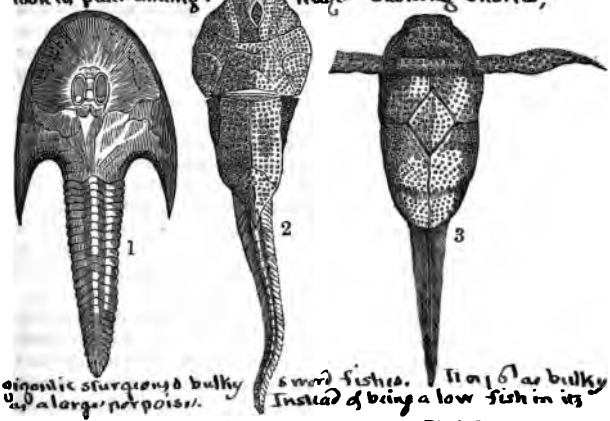
Agassiz has announced that two genera of shark of the division Cestracean occur in the Devonian beds of Russia. —

The preceding synopsis represents the usual order of the system as it occurs in Scotland. All of these groups are well marked in the field; and when treated not as distinct systems, but as portions of one great system, materially aid the investigations of the geologist.

173. *The organic remains of the system*, if not so numèrous as those of the grauwacke beneath, or the carboniferous measures above, are at least equally interesting, on account of their peculiarities and adaptation to the conditions under which they were destined to exist. The remains of plants are few and indistinct; but are apparently allied to those found in the true silurian rocks. In the tilestone group have been found impressions of ferns, equisetaceæ, leaves resembling those of the flag and flowering rush, and circular markings like the floral envelopes or berries of some shrubby plant. Most of these are highly carbonised and broken, as if drifted from a distance by water, and deposited among the sandy material in which they are now imbedded. A few carbonaceous layers occur among the schistose beds; but vegetable matter nowhere abounds in sufficient quantity to form bituminous layers or thin seams of coal. Taken as a whole, the old red sandstone system is particularly barren of vegetable remains, and seems to evince a condition of the earth which did not permit of the growth of plants unless in detached and limited areas; these plants being by no means high in the scale of vegetable organisation. Its animal remains are more abundant and distinct; but present little variety—the prevailing types being marine fishes of simple but curious structure.

174. *The fossil fishes, or ichthyolites, of the old red sandstone*, present the first distinct trace of the existence of the highest division of the animal kingdom; namely, *vertebrata*. It must be remarked, however, that the earliest genera are not of the most perfect structure; but form, as it were, a link between the humbler crustacea and fully-developed fishes. The *cephalaspis*, *coccosteus*, and *pterichthys*, represented in the following engraving, are the most prominent types of these crustacean-like families. The cephalaspis, in general figure, resembles the *asaphus* of the silurian rocks, is covered with bony plates, and takes its name from the buckler-shape of its head (Gr., *kephale*, the head, and *aspis*, a buckler). The coccosteus is also enveloped in a bony covering, is furnished with a tail for locomotion, and takes its name from the berry-like tubercles which dot its plates (Gr., *kokkos*, a berry, and *osteon*, a bone). The pterichthys has the same kind of covering or external skeleton; but its distinguishing feature is a pair of wing-like appendages, which seem not only to have aided

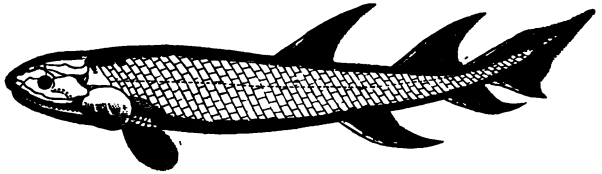
in locomotion, but to have reared defensively when attacked. It takes its name from these appendages (Gr., *pteron*, a wing, and *ichthys*, a fish), and is one of the most abundant fossils in this formation—being as characteristic of the old red sandstone



1. Cephalaspis. 2. Coccosteus. 3. Pterichthys.

as the trilobite was of the silurian rocks. In the *holoptychius* (figured below), and some others, this bony covering prevails; but it is formed of a greater number of plates finely enameled

ranged, so as to join or overlap each other. This structure is well illustrated by the *osteolepis* (Gr., *osteon*, a bone, and *lepis*, a scale), which presents the form of a perfect fish furnished with pectoral, abdominal, and caudal fins. In the osteolepis (see figure) the bony scales are placed alongside each other like the bricks in a building; calculated at once to afford a strong protection to the internal parts, and to yield to the bendings of the body while in motion. In the previous forms of animal life, the organs of motion are but imperfectly developed;



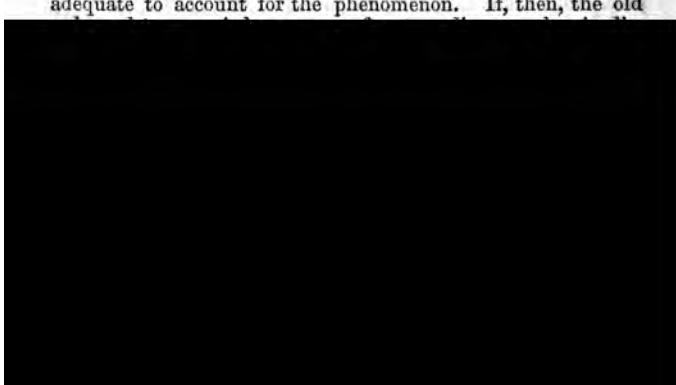
Osteolepis.

but in the osteolepis a great advance is exhibited, its fins, tail, and elongated form of body being such as to combine strength with agility. Some families of these early fishes are furnished with spiny fins, or are otherwise armed with detached spines from two to five inches in length, and which are known to geologists by the name of *ichthyodorulites* (Gr., *ichthys*, a fish, *doru*, a spear, and *lithos*, a stone). In all of them the tail is unequally lobed, like that of the shark—a character which distinguishes cartilaginous from osseous fishes; the shark, dog-fish, sturgeon, &c. belonging to the former, the cod herring, salmon, &c. to the latter division. (Par. 181.)

175. *From what we have seen of the fossil flora and fauna of this system*, they seem to indicate a condition of life higher in point of development than that which existed during the deposition of the grauwacke and silurian rocks. The cephalaspis, coccosteus, and ptericthys, are successive advances upon the simply organised asaphus; and the holoptychius, osteolepis, and glyptolepis, belong to orders still more fully developed than the ptericthys. But while this advance in the scale of organisation took place, some peculiarity in the waters of the ocean, or other condition, seems to have prevented the increase of previously existing orders; for in none of the beds of the old red sandstone do we find the corals, shell-fish, and crustacea of the silurian system. It is true that in the lower, or flagstone series, remains of crustaceans have been discovered; but in such an imperfect state, that it is impossible to decide what analogy they bear to those of the silurian limestones.

Again, the vegetation which existed during the formation of the grauwacke rocks seems to have vanished almost entirely while the deposition of the old red sandstone was going forward; for, unless at a few detached points, do we find anything like a vegetable organism throughout the whole mass of the formation.

176. *The conditions of the world during the deposition of the old red sandstone* are but imperfectly indicated by the fossil organisms to which we have adverted. Flanking the primary and transition hills, the old red sandstone is eminently a littoral deposit, the lower or gray micaceous series evincing sediment in calm water, the sandstone and conglomerate beds the action of currents and other aqueous agitation, and the yellow beds a recurrence of calm deposition. Many of the strata present the *ripple mark* of the tide as perfect as that now to be traced on the sands of the existing shore; and the conglomerate throughout its entire composition points to causes analogous to those by which the gravel-beaches of the present day are collected. The colouring matter (peroxide of iron) of the formation shows that the waters must have been impregnated with mineral solution, so as to be deleterious to animal life; and it is a curious corroboration of this fact, that the fossil fishes are most abundantly found in the flagstone and yellow sandstone series—the strata least coloured by the metallic impregnation. Whence the metallic oxide was obtained by which the formation is more or less tinged throughout, is a matter of hypothesis among geologists; but that opinion which ascribes it to volcanic origin is the most commonly entertained, and indeed the only one which seems adequate to account for the phenomenon. If, then, the old



said to have passed away, and to have been succeeded by that of the *trap*—an era which produced more complicated displacements and contortions of the stratified rocks, though less extensive and gigantic elevations. In Scotland, the Grampians belong to the former era, the Ochils to the latter; two ranges which, even to the untutored eye, present so many points of dissimilarity both in their external contour and internal composition, as at once to be ascribed to different eras. The volcanic forces which were smouldering throughout the whole formation of the old sandstone, seem, at the conclusion of the deposit, to have spent themselves in one gigantic paroxysm, and to have upheaved the newly-consolidated strata into mountain ridges of extreme irregularity, along whose flanks, as they extended seaward, were deposited *unconformably* the strata of the succeeding formation.

178. *The extent of country occupied by the old red sandstone* is very great, owing, in many instances, to the flat position of the strata, which thus cover a larger amount of surface than they would have done had they been highly inclined like the primary formations. All the members of the series are widely developed in Scotland; the lower portions occur between England and Wales, in Ireland, and in Germany; the middle portions occupy extensive areas in Russia and the flats of Central Europe, in Siberia and Tartary, and flank also the southern Himmalehs; and different members of the system occur in various districts of North and South America, as well as in Central Africa.

179. *The geographical features of red sandstone districts* are in general varied and irregular; the hills being less bold and precipitous than those of primary formations, and more lofty and undulating than those of any subsequent period. Where the strata lie flat, and comparatively unbroken, the scenery is rather uninteresting; but the soil is light and fertile, being based on sand, gravel, or reddish clay, composed of the debris of the formation. On the other hand, the mountains of the old red sandstone exhibit great diversity of scenery: rising in easy undulations, sinking and swelling in every direction, yet preserving a common continuity of range, they present in the chain a succession of rounded heights and cones; but in the mass, an irregular surface of hills and valleys, glens and recesses, of great beauty and amenity. The Ochils and Sidlaws, in Scotland, with their intervening valleys, belong exclusively to this formation, and may be taken as the type of its physical features.

180. *The minerals of commerce* derived from the old red sandstone are comparatively few. From the lower group of

beds are obtained those thin schists of gray micaceous sandstone so generally employed in foot-pavements, in roofing and in flooring; hence the terms *tilestone* and *flagstone*. From the superior red and yellow groups, building-stones of various quality are obtained; but none of these are of great beauty or durability. The claystone, porphyries, and felspars, are exceedingly durable; but are seldom used by the builder, owing to the difficulty of hewing them into form. From the trap, some of the best material for macadamising is obtained in the lowlands of Scotland; while among the debris of the same rocks, the lapidary finds many *geodes* of the finest chalcedonies, agates, jaspers, and carnelians.

Ganoids appear first in the Lower Old Red Sandstone.
Placoids ?
Have V gills ?

CLASSIFICATION OF FOSSIL FISHES.

181. Before proceeding with our description of the succeeding formations, it will be necessary to advert to the system of classification which has been adopted in reference to fossil fishes, inasmuch as it differs from that which Cuvier applied to existing races. This celebrated naturalist collected the whole number of species into two groups, according to the nature of the skeleton and the hard parts—one group embracing the OSSEOUS, or bony, and the other the CARTILAGINOUS fishes. The former group he further separated into two orders—the *Acanthopterygian*, or thorny-finned, and the *Malacopterygian*, or soft-finned. This method, however, does not meet the wants of the geologist, because the skeleton is seldom or ever found in such a state as to answer the purposes of classification. Fossil scales, teeth, spines, and fragments of fishes, are found in abundance, but these afford too imperfect data for arrangement; and

ing is a sketch of the principal divisions and subdivisions proposed by M. Agassiz :—

I.—SCALES ENAMELED.

1. GANOIDIANS (Gr., *ganos*, splendour, from the bright surface of their enamel).—The fishes of this order are covered with angular scales, composed internally of bone, and coated with enamel. The scales are *regularly* arranged, and entirely cover the skin. The sauroid fish, or those which, from the structure of their teeth and other peculiarities, approximate to reptiles, are amongst the most interesting of this order. Nearly all the species referred to it are extinct; the *sturgeons*, and *bony-pike* of the North American lakes, are living examples.

2. PLACOIDIANS (Gr., *plax*, a broad plate).—Fishes of this order have their skin covered *irregularly* with plates of enamel, often of considerable dimensions, but sometimes reduced to small points, like the shagreen on the skin of the shark, and the prickly tubercles of the ray. It comprehends all the cartilaginous fishes (*sharks* and *rays*), with the exception of the sturgeon.

II.—SCALES NOT ENAMELED.

3. CTENOIDIANS (Gr., *kteis*, genitive *ktenos*, a comb).—Ctenoid fishes have their scales of a horny or bony substance without enamel, jagged like the teeth of a comb on the outer edge. The *perch*, and many other existing genera, are of this order, which contains but few fossil forms.

4. CYCLOIDIANS (Gr., *cyclos*, a circle).—The fishes of this order have smooth, horny, or bony unenameled scales, entire at the margin, with concentric or other lines on the upper surface. The *herring*, *salmon*, &c. belong to this order, which, along with the former, includes almost the whole number of existing species.

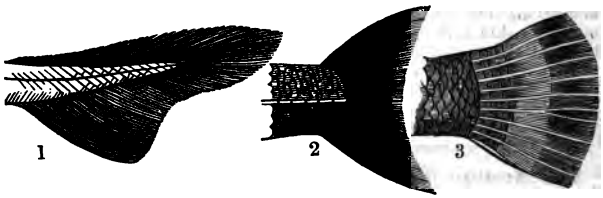
Such are the divisions proposed by M. Agassiz, and now universally adopted by geologists, although it is not unlikely that a more perfect system may soon be propounded, which will embrace in one category both fossil and existing species. The subjoined engraving more summarily represents the four orders of scales above alluded to :—

1, Ganoid; 2, Placoid; 3, Ctenoid; and, 4, Cycloid, Scales.

183. *Each of these orders contains both bony and cartila-*

" this fish moving its head upon the neck freely, right & left & upwards, as a saurian, and as no other fish in
100 " GEOLOGY.
creation does. / Wilnor, Oct. 23. 1838

ginous fishes. The representatives of each prevailed in different proportions during different epochs; the two first (enameled scales) existed before the commencement of the chalk system; the third and fourth orders, which contain nearly five-sixths of living species, appear for the first time in the chalk strata, when all the preceding fossil genera of the two first orders had become extinct. Another remarkable circumstance observed by M. Agassiz is, that all, or nearly all, the fossil fishes found in strata beneath the magnesian limestone are *heterocercal*, that is, have their tails *unequally bilobate* (see fig.), like the shark, sturgeon, lepidosteus, &c.; while this form of tail is rarely found in the oolite and superior strata. Among existing fishes,



1. Heterocercal, or Unequally bilobate; 2. Equally bilobate; and, 3. Single and rounded, forms of tail.

the tail, or caudal fin, is generally *equally bilobate*, as in the trout; or *single* and rounded, as in the wrasse; but seldom heterocercal. This latter form is produced by a remarkable prolongation of the vertebræ, which bears a striking analogy to the prolongation of the same parts in reptiles: thus

cut and polished, they resemble a section of a plum-pudding; hence the term *puddingstone.*

PORPHYRY (Gr., *porphyra*, purple).—This term was originally applied to a *reddish* unstratified rock found in Egypt, and used by the ancients for statuary purposes. It is now employed by geologists to denote a reddish igneous rock containing imbedded crystals of felspar; and all rocks (whatever their colour) which contain imbedded crystals distinct from their mass, are said to be *porphyritic.* We have thus felspar porphyry, porphyritic granite, and porphyritic greenstone.

AMYGDALOID (Gr., *amygdalon*, an almond, and *eidos*, a form)—almond-shaped. The term is applied to certain trap rocks in which other minerals are occasionally imbedded like almonds in a cake. Some varieties of amygdaloid are locally termed *toad-stones*, from the resemblance which their colour and markings bear to that of a toad's skin.

GEODES (Gr., *geodes*, earthy)—a term applied to rounded pebbles having an internal cavity lined with crystals; also to rounded or nodular pebbles themselves; and to nodules of ironstone hollow in the centre.

CARBONIFEROUS SYSTEM.

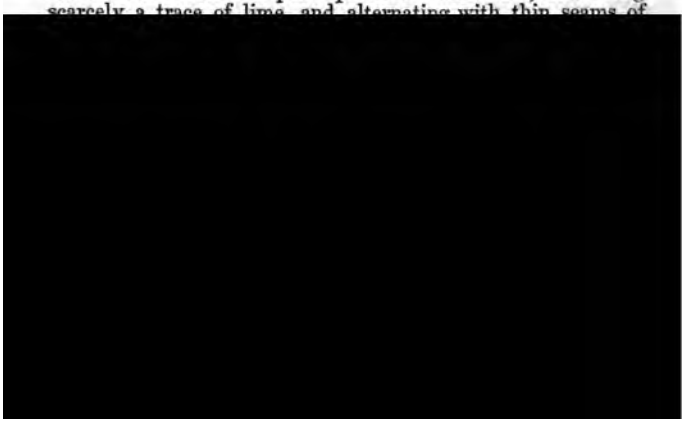
184. At the close of the Old Red Sandstone period the earth seems to have undergone an almost total change in its geological conditions. The red sandstones and gravelly conglomerates which had been formed along the shores and bottom of the sea, were upheaved into dry land; thus adding to the extent of land previously existing, and gradually circumscribing the limits of the ocean in which subsequent deposits were to take place. As disintegrated granite furnished the felspar, quartz, and mica of the gneiss and mica schist, and as from these, again, were obtained the materials of the clay-slate, grauwacke, and silurian rocks, so from all these, together with the newly upheaved red sandstone, were derived the material of the succeeding formation. These successive attritions would reduce quartz to sand of various fineness, felspar to loose impalpable clay, mica from large plates to minute scales, and crystalline limestone to a dully powdery consistence. The rocks formed of these ingredients would necessarily present a less compact texture; and thus it is in the Carboniferous System that the sandstones are more arenaceous, the shales soft and earthy, and the limestones non-crystalline and often impure. Besides the sandstone, clay, and limestone, two new rock substances make their appearance among the strata of this system, namely, *coal* and *ironstone*—the former being the result of compressed and altered vegetation, and the latter a chemical aggregation of the metallic particles around some earthy basis. The iron of the old red sandstone was

disseminated through the mass as mere colouring matter; in the carboniferous formation it is principally collected in layers, or in nodules. The vegetation of previous periods was so scanty, as to leave only a few dubious impressions among the strata. During the era about to be considered, it was so abundant, as to form numerous beds of coal, ranging in thickness from a few inches to twenty or even thirty feet.

185. *The term "Carboniferous" has been applied to this system* from the fact, that vegetable deposits—of which the main solid element is *carbon*—constitute its most distinguishing feature. It is regarded by many as marking the commencement of the SECONDARY PERIOD; and holds a position in the earth's crust intermediate between the old and new red sandstones. Having been deposited after the upheaval of the old red sandstone, it rests in many places unconformably upon that system, and occupies smaller and more detached areas, which often assume a basin or trough form, as shown in page 116. It is composed of two very distinct groups, the *mountain limestone* and the *coal measures*, which in some respects require separate descriptions.

MOUNTAIN, OR CARBONIFEROUS LIMESTONE.

186. *The distinguishing feature in the mineral composition* of this group is sufficiently indicated by the name Mountain Limestone. It must not be supposed, however, that it is entirely composed of calcareous beds; but merely that the limestones are the most characteristic members; for many of the inferior strata are pure quartzose sandstones, containing scarcely a trace of lime, and alternating with thin seams of



(or *backs*, as they are called by quarrymen) perpendicular to, and the latter *partings* parallel with, the plane of stratification.

187. *The order of succession among the strata of this group* is by no means determinate. In some districts, only a few beds of calcareous shales and grits occur between the limestone and old red sandstone; in others, a vast succession of white quartzose sandstones alternating with bituminous shales, thin seams of coal, and bands of ironstone; while in Fife and Mid-Lothian, these sandstones are associated with strata of shell and fresh-water (?) limestone. Whatever may be the character or thickness of the rocks beneath, the true mountain limestone of itself constitutes a well-marked suite of strata, easily distinguishable from any other. Sometimes it consists of two, four, or six beds, divided by partings of argillaceous matter; at other times the beds are separated by layers of calcareous sandstone and shale; while not unfrequently it occurs in one mass of vast thickness, flanking some trap-hill precisely after the manner in which a coral reef skirts the island around which it is forming. In general, there occur above the limestone calcareous shales, sandstones, and thin seams of coal, which pass into the true coal measures; but in the north of England, there intervenes a series of very pebbly or quartzose sandstones, known by the name of *Millstone Grit*. Notwithstanding these variations, the calcareous members gradually disappear, and the carboniferous become more frequent as we ascend, so that there is no great difficulty in fixing the line of demarcation between the two groups.

188. *The organic remains of the mountain limestone* are eminently marine. It is true that the occurrence of thin seams of coal attest the presence of terrestrial plants which must have been drifted into the sea of deposit; and there is some doubt among geologists as to the origin of certain limestones among the lower strata; but laying these aside, the whole character of the group is as decidedly oceanic as the living coral reefs of the Pacific. The most remarkable advance upon the marine life of former periods, as evidenced by the fossils of the mountain limestone, is that which appears among the Radiata. In the silurian rocks, the corals were chiefly of a sessile kind; in this group many of them are free and independent animals, bearing little or no analogy either to previous or existing forms. The most prevalent of these was the *Crinoid* or *Encrinite* family, of whose exuviæ many beds of limestone are almost wholly composed. Of the encrinite (Gr., *krinê*, a lily), or lily-shaped corals, are found many genera and sub-genera—the distinctions being made

In Lily Encrinite 26000 bones. In Briarean Pentacrinite 150000. Each bone furnished a 2 fasciculi (answering to muscles) = 300,000 fasciculi / Number ~ bones 1 human body = 241 muscles 232 pairs. In Dragon Fly 170

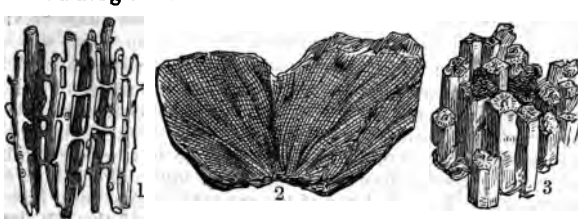
from the external figure of the stalk and head. That exhibited in fig. A may be taken as the type of the class; it is the *encrinites moniliformis*, so called from the necklace-shape of its stalk. Besides the encrinites moniliformis, which is by far the most prevalent of the crinoideans, there were the *pentacrinus*, five-sided instead of round, the *actinocrinus*, or spiny encrinite, the *apiocrinite*, so called from the pear-like form of its head, and many others deriving their names from similar distinguishing features. By examining fig. A, the student will perceive that the encrinite consisted of a stalk composed of numerous joints, rendered flexible by means of cartilage, and perforated for the passage of an internal canal; that it was fixed at its base, and supported at its free extremity, a cup-like body (*s*) containing the mouth and stomach; that this cup-like body was composed of many pieces, which branched out into numerous tentacula (*t*) for the purpose of seizing its prey. The whole animal is supposed to have been invested with a gelatinous covering, by which its structure was held together. In the skeleton of some specimens, not less than 26,000 bones, or pieces of cal-

Encrinites Moniliformis.

tain or encrinital limestone, which, when sufficiently hard, furnishes a curious and highly ornamental marble.

Fig. B.—Fragment of Encrinital Limestone.

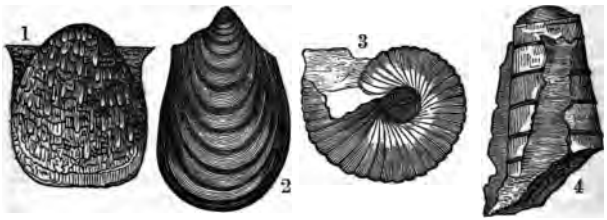
189. *Besides crinoidea, the mountain limestone contains many other species of radiaria*—branched, fungous-shaped, fan-shaped, star-shaped, and tubular. These differ in many instances from the corals of the silurian, as they differ from those of the present day; and are confusedly mingled with corallines, shells, teeth, spines, and scales of fishes. The following engraving represents some of the more prevalent forms among the corals and corallines of this era :—



1. Syringipora. 2. Retepora. 3. Cyathophyllum basaltiforme.

190. *The shell-fish of this group* are also exceedingly numerous, and of curious and gigantic forms. They belong to all orders—equal and unequal bivalves, single and many-chambered univalves; many of them are not to be found in any other strata than those of the carboniferous era. Several families seem (like the oyster and cockle of the present day) to have been gregarious, covering large spaces

of the ocean's bed; for shells are found composing beds of limestone from one to six feet in thickness; others to have been solitary, changing their places as necessity required; while the chambered shells, like the argonaut and nautilus, possessed the power of sinking or floating at pleasure. (See par. 222.) Like existing shell-fish, they appear to have inhabited the seas at moderate depths from the shores, and to have preyed partly on each other, and partly on marine vegetables. Their numbers and size indicate a genial condition of the ocean both as regards temperature and calcareous matter—the former fostering their growth with rapidity, and the latter yielding material for the structure of their shelly coverings. Some of the more typical shells belonging to this formation are the Producta, Terebratula, Spirifera, and Inoceramus among the bivalves; and the Euomphalus, Ammonite, Bellerophon, Orthoceratite, and Goniatite among the univalves, which are chiefly many-chambered.



1. Producta scabriculus; 2. Inoceramus vetustus; 3. Bellerophon tangentialis; 4. Orthoceras cinctum.

palatal bones, spines, and teeth are found in abundance, some of the latter being more than four inches in length—thereby denoting the gigantic size of these predatory animals. Their coprolites (Gr., *kopros*, dung, and *lithos*, a stone), or fossil excrements, are scattered throughout the shales and calcareous strata, and attest, by the fish-scales, bones, &c. which they contain, the nature of the food on which they subsisted.

COAL MEASURES.

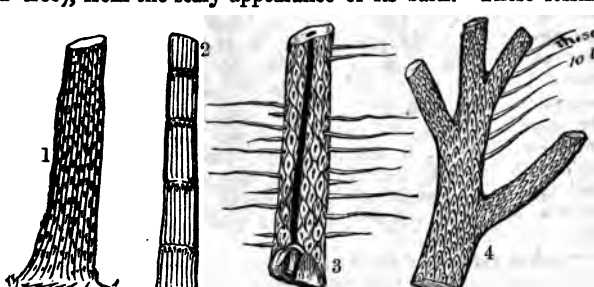
192. *The term "Coal Measures"* is applied to that series of rocks which immediately overlies the mountain limestone, and from which the well-known mineral, *coal*, is obtained. The group is composed of alternations of coals, sandstones, shales, bands of ironstone, fire-clay, and layers of impure limestone. The coals present every degree of fineness and purity, and are generally distinguished as follows:—*Anthracite*, a hard, shining variety, destitute of bitumen, often called mineral charcoal; *caking*, a highly bituminous sort, like that of Newcastle, which cakes or runs together during combustion; *cubic*, less bituminous, breaking up into cubical masses; *cannel*, a compact lustrous variety, which breaks with a conchoidal fracture; *jet*, still more compact and lustrous; and *lignite*, or brown coal, in which the woody structure of the vegetables is still perceptible. The sandstones are in general quartzose, of a dull-white or brown colour, and thick-bedded; sometimes they are flaggy, or schistose, and in this instance are either of a calcareous or argillaceous character. The shales are all dark-coloured, and bituminous; the fire-clays grayish-white, and more or less sandy; the ironstone occurs either in bands or nodules; and the limestones are all earthy and impure. The ironstone of earlier formations occurs either in veins, or is disseminated as colouring matter through the mass; in this system it appears as an argillaceous carbonate, either in thin layers from one to twelve inches thick, in irregular nodules, or in bands of regular nodules, called *septaria*, from the nodule being often internally divided into numerous *septa*, or partitions, as shown in 4 of the following engraving. These nodules seem to have been formed by some process of attraction round a central nucleus, as in nine cases out of ten they contain nuclei of leaves, teeth, scales, or spines of fishes, coprolites, or some other organic matter. Beneath is represented as central nuclei—1, a fragment of a plant; 2, a fish-tooth; 3, fossil excrement, or coprolite; and, 4, true septaria, with their curious partitions of white carbonate of lime, giving the section the appearance of a beetle; from

which circumstance such nodules are known in some places as *beetle-stones*.

Ironstone nodules, showing varieties of central nuclei.

193. *There is no regular succession among the beds of this group;* though it may be remarked, that the thickest and best seams of coal abound about the middle of the series. Immediately above the mountain limestone the coal beds are thin, the shales thick-bedded, and more or less calcareous; and the sandstones often calcareous and argillaceous. As we ascend, the argillaceous and calcareous members become less prevalent, the coals thicker and more frequent, and the shales more bituminous. Further up in the series, the coals gradually disappear, fire-clays and light-coloured shales abound, the sandstones become more purely arenaceous, assume various shades of colour, and insensibly pass into the superincumbent new red sandstone. In general, all the members alternate indiscriminately with each other, present various degrees of fineness, colour, and mineral composition, and are persistent over extensive areas. Occasionally, a stratum will *thin out* and disappear: at other times it will

this way Mr Witham observed the various vegetable tissues in coal, thereby adding another testimony to the numerous evidences of its organic origin. In most of the bituminous beds, however, the external form is obliterated, and it is to detached fossils in the sandstones and lighter shales that the geologist is indebted for his knowledge respecting the Flora of the carboniferous era. About four hundred species have been already determined, chiefly gigantic equisetums, ferns, club-mosses, cactuses, pines, and plants allied to the bulrush, cane, and bamboo. Most of these resemble existing plants merely in their generic distinctions, having belonged to species which flourished during the coal-forming period, and became extinct with the peculiar conditions of the globe which gave them birth. Some of the most characteristic of the vegetable fossils belonging to this formation are represented beneath; namely—1. *Sigillaria*, so called from the graven appearance of its stem; 2. *Calamites*, from the reed-like jointings of its stalk; 3. *Stigmaria*, from its stigmata, or punctures; 4. *Lepidodendron* (Gr., *lepis*, a scale, and *dendron*, a tree), from the scaly appearance of its bark. These fossils



1. Sigillaria pachyderma; 2. Calamites cannæformis; 3. Stigmaria ficoides; 4. Lepidodendron Sternbergii.

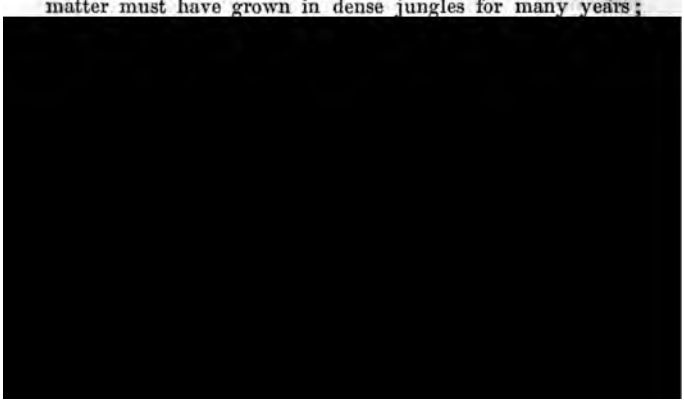
occur in all the members, from the lowest white sandstone beneath the mountain limestone, up to the commencement of the new red sandstone, at which stage they disappear, and do not seem to have flourished during the deposition of any subsequent formation. The best preserved specimens are found in the shales and sandstones; the interior structure of the plant being converted into soft quartzose sandstone, and the bark, or cuticle, into a glistening bituminous coal. In the coal, the vegetable structure is always more or less obliterated, though sometimes a solitary trunk occurs of the same quart-

zose material as those imbedded in the shales and sandstones. Of these fossil trees, many have been found of gigantic dimensions; as, for example, a lepidodendron in the Jarrow coal-field 13½ feet wide at the base, and 39 feet high, exclusive of the branches at the top, which were also entire; and a conifera of the genus *auracaria* in Craigleith quarry, 3 feet in diameter, and 20 feet long. Besides the sigillaria, &c. above described, there are numerous species of tree-ferns, club-mosses, equisetums, and other cryptogamic plants preserved in the shales; their dark carbonaceous leaves and branches being often beautifully displayed upon the light-coloured ground of the material in which they are imbedded. Of these the following engraving exhibits some of the most characteristic; namely, *Asterophyllites* (Gr., *aster*, a star, and *phyllon*, a leaf); *Sphenopteris* (*sphen*, a wedge, and *pteron*, a wing); *Pecopteris* (*pekos*, a comb, and *pteron*, a wing); all so named from the shape of their respective leaves.

sandstones, at another clay and mud to form shale, and at a third period vegetable drift to form coal; for strata of these materials often directly overlie each other. It must be borne in mind, however, that sand, clay, and plants, might be carried down at the same time, and that they would arrange themselves according to their gravity—the sand depositing itself along the shores, the mud farther seaward, and the vegetables in any still bay where currents of wind or water might drift them. Such an arrangement would take place under the ordinary operations of water; but during violent inundations, there would be a confused intermingling of sand, mud, and plants, and this we often discover; so that, taking all things into account, we learn that the same agencies of rivers, waves, and tides, existed during the deposition of the carboniferous rocks as exist at the present day, only on a more gigantic and uniform scale. Looking at the abundance of marine life which must have thronged the waters during the formation of the mountain limestone, and at the vast amount of vegetation which the earth must have sustained while the deposition of the coal measures took place, we are led to infer that the earth then enjoyed a much higher and more uniform temperature than it has ever since experienced. At present, we find a faint analogy in the Fauna of the tropical seas, and in the Flora of the tropical jungles, to those of the carboniferous era; but so faint, that we can scarcely institute a comparison between the results produced. The coral-reefs of the Pacific are insignificant compared with the thickness and extent of the mountain limestone; and the vegetable drift of the Mississippi and Ganges combined, would scarcely produce carbonaceous matter sufficient to colour one stratum of shale. Notwithstanding this, there is a resemblance between the coral productions of the Pacific and those of the mountain limestone; and between the palms, tree-ferns, canes, and cactaceæ of the tropics, and the fossil plants of the coal measures. The heat of the tropics is directly derived from the sun, and the torrid zone occupies but a narrow belt of the earth's surface; whereas the coal measures are to be found almost in every region of the globe. The sun could not, therefore, have yielded that temperature which nourished the plants and animals of this period; for though the sun's heat had been greater than at present, it could not have been universally diffused. The conclusion, therefore, to which most geologists have come, is, that the earth, originally an incandescent mass, was gradually cooled down—hot enough to render gneiss and mica schist crystalline; cool enough during the grauwacke and silurian eras to permit of marine corals, shell-

fish, and crustacea; cooler still during the life of the plated fishes of the old red sandstone; and only sufficiently genial throughout the deposition of the carboniferous period to foster a growth of terrestrial vegetation all over its surface, to which the existing jungles of the tropics are mere barrenness in comparison. This high and uniform temperature, combined (as suggested by Brogniart) with a greater proportion of carbonic acid gas in the atmosphere, would not only sustain a gigantic and prolific Flora, but would also create denser vapours, showers, and rains; and these, again, gigantic rivers, periodical inundations, and deltas. Thus all the conditions for extensive estuary deposits would arise from this high temperature; and every circumstance connected with the coal measures points to such conditions.

196. *With regard to the formation of coal,* geologists are not yet fully agreed. On examining sandstone or shale, it is easy to perceive from their structure, texture, and composition, that they must at one time have been respectively loose sand and mud, borne down and deposited by water; but the case is somewhat different with beds of coal. This mineral, being chiefly composed of carbon, hydrogen, and oxygen—the same elements which enter into the composition of plants—and revealing in its mass evidence of vegetable structure, no doubt is entertained of its organic origin. But whether the plants of which it is composed were drifted down by rivers, and deposited along with layers of mud and sand in estuaries, or whether dense forests and peat-mosses were submerged, and then overlaid by deposits of sand and mud, are the questions at issue. According to the latter hypothesis, the vegetable matter must have grown in dense jungles for many years;



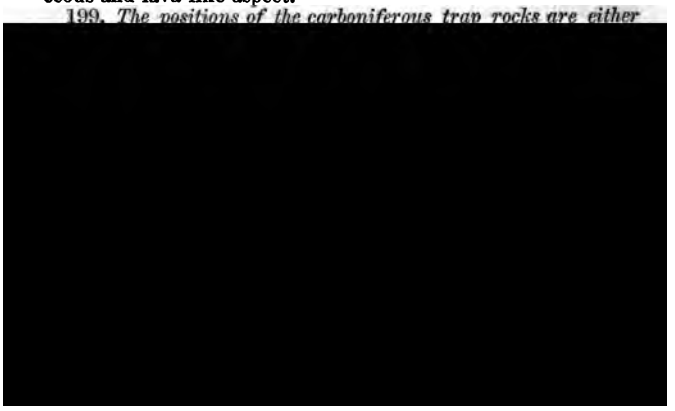
themselves into one estuary, some chiefly carrying down sand, while others transported plants, mud, and heterogeneous debris. This theory also supposes that the transporting rivers were subject to periodical inundations, and that, during the intervals of overflow, the deltas were choked with a rank vegetation, which, in conjunction with the vegetable drift from inland, went to the formation of beds of coal.

197. *Both theories are at present beset with many difficulties;* but the latter is the more generally received, as accounting for most of the phenomena connected with our coal-fields. According to the former theory, a submergence and elevation must have taken place for every seam of coal; and as in some districts from thirty to forty seams occur, varying in thickness from a few inches to many feet, it is impossible to conceive how the earth, in this unstable condition, could have nourished such a prolific Flora as the coal measures clearly demonstrate. It is also justly objected against this theory, that some thick beds of coal are subdivided by thin layers of sandstone, or ferruginous shale, a fact which would imply that many elevations and submergences took place even during the formation of a single coal bed; whereas by the latter theory, those layers of sandstone, &c. present no difficulty, as the river, while it bore down vegetable drift, would carry at the same time sand and other debris. Further, shells and fishes are sometimes found imbedded in coal; and it is difficult to conceive how these could have got there, unless in the ordinary way of deposit and sediment. Forests of coniferæ, palms, and tree-ferns, could not have been submerged and covered up with sand and mud, without the trunks being abundantly found in an upright position; now, this upright position of fossil trees is rarely or ever met with. Again, had coal resulted from submerged peat mosses, instead of from growing forests, there is no means by which we can account for the occurrence of shells, fishes, and thin layers of sandstone in its mass. By the latter theory, all these can be readily accounted for. Over vast deltas, such as those in which it supposes the coal measures to have been deposited, there would not only occur growing stems of palms, ferns, reeds, and the like, to be silted up perpendicularly, but there would also occur morasses choked up with a rank growth of grasses, while in the creeks and lagoons, shell-fish, fishes, and other aquatic life would abound. In the deltas of existing rivers, the latter theory meets with a perfect analogy; and when the student is told of the rafts of the Mississippi, the mangrove jungles of the Niger, and the sand and mud-banks of the Ganges (par. 279, 280, &c.), he can have little

difficulty in forming a conception of the estuaries in which the sandstones, shales, shell limestones, and coal of the carboniferous era were deposited.

198. *The igneous rocks associated with the carboniferous system* are all of the trap family—greenstones, clinkstones, basalts, trap-tuffs, &c. They are principally composed of felspar and hornblende, with admixtures of clay, augite, and occasionally hypersthene. The *greenstones* (vulgarly, whinstones) occur in large indeterminate or tabular masses, and are often hypersthenic; the *clinkstones* differ little from the greenstones in mineral composition, but are more compact, split up into thin schistose-like fragments, and yield a metallic sound when struck by the hammer; the *basalts* are easily known by their columnar structure, their dark and compact aspect, and from their containing little spherical crystals of a greenish mineral called *olivine*; and the *trap-tuffs* are of all varieties, from a soft scoriaceous-looking mass to a confused conglomerate of fragments of basalt, greenstone, sedimentary rocks, &c. The trap rocks of the carboniferous era are easily distinguishable from those of any other, partly by their darker colour, and from the fact of their yielding more or less bitumen by distillation; and partly from the prevalence of basalts, and of trap-tuffs containing fragments of limestone, sandstone, and shale. Among the traps of the old red sandstone, felspar, porphyries, and amygdaloids prevail, but are rarely to be met with among those of the coal measures; while, on the other hand, the traps associated with the tertiary strata assume a lighter colour, and a decidedly scoriaceous and lava-like aspect.

199. *The positions of the carboniferous trap rocks are either*



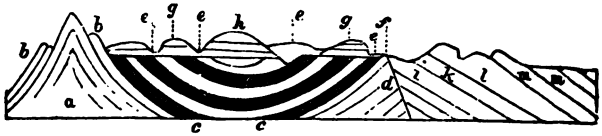
distinctly crystalline than the former, and more compact and less vesicular than the latter. The structure of the tuffs and porphyries is massive and indeterminate; of the greenstones sometimes massive, but generally tabular or cuboidal; and of the basalts always columnar. This difference in the structure and texture of these rocks seems to have arisen not so much from any difference in their mineral composition, as from the circumstances attending their cooling. This has been satisfactorily proved by the experiments of Sir James Hall and Mr Gregory Watt, who, by fusing various kinds of trap, produced, by different modes of cooling, not only columnar basalt, but spherical greenstone and vesicular tufa. The same substance which, when suddenly cooled, forms a black glass or *obsidian*, will, by a slower process of refrigeration, form basalt, or, by a still slower, pass into earthy tufa. By gradually cooling the fused mass, columnar basalt may be formed; but if, at a certain stage of the process, it be rapidly cooled, spherical masses will be produced, which, when exposed to the weather, *exfoliate*, or decompose coating after coating. By these experiments, it was also proved that the primary form or crystal into which volcanic rock arranges itself when cooled, is spherical; and by these spheres pressing

Staffa—Fingal's Cave.

upon each other, are produced tabular, cuboidal, and columnar forms. This fact can be readily illustrated by putting a number of spherical pellets (of putty or any other yielding

material) into a vessel, and then gently pressing upon them, when they will be seen to arrange themselves in five and six-sided columns, precisely similar to the five and six-sided columns of Staffa, or the Giant's Causeway.

201. *The effect of igneous forces upon the coal measures* has been to throw them into troughs and basins, to elevate and depress them in a very extraordinary manner. The following engraving represents a section of the South Gloucestershire coal-field (omitting faults), and may be taken as the type of the *trough* or *basin*. Here *a* is the elevatory axis of the



Trough or Basin Form of Coal-fields.

Mendip hills, overlaid by the old red sandstone *d*; *b b* are strata of carboniferous limestone resting at a high inclination upon the slopes of the hills, and reappearing at *f*; *c c* and the other darkened layers are beds of coal; *e e e* denote the new red sandstone lying unconformably upon the coal measures; *g g* detached outliers of lias; and *h* is a detached outlier of inferior oolite, which are respectively continued in *i* and *k*; *l* is the upper oolite, and *m m* are beds of Oxford clay situated to the north of the town of Malmesbury. The *upthrows* and *downthrows* of the coal strata, which have taken place in

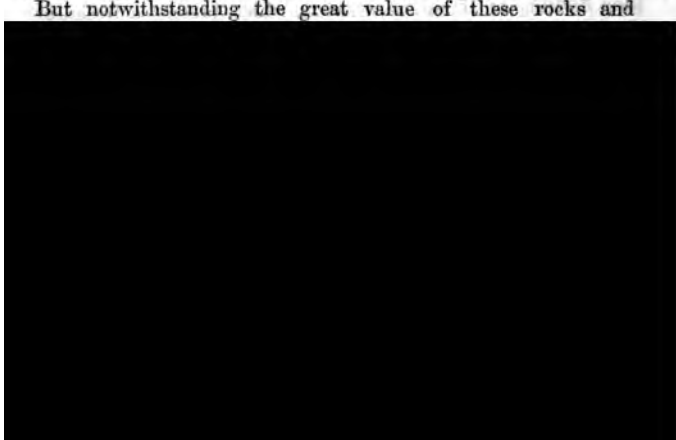
miles each way, the coal-field shows 120 ascertained dislocations, one of which, at Sheriffhall, throws down the strata 500 feet. In the Newcastle coal-field, there is a famous slip called the *ninety-fathom hitch*, the deviation from the line of stratification being no less than 450 feet. The coal-fields of Fife and Clackmannan abound in such dislocations, several of them throwing the strata from 400 to 1200 feet up or down, as the case may be, from the general position.

202. *The extent of country occupied by the carboniferous system* is not great, the deposit being found only in limited and detached areas. It occurs largely in the British islands, and to this circumstance is mainly owing our greatness as a nation—the formation being rich in coal, iron, and lime—three of the most essential minerals to civilised existence. It presents itself in the Lowlands of Scotland, in the northern and middle districts of England, in Wales, and in Ireland; it occurs also in some districts of Spain, in central France, Germany, and in Middle Europe; in Hindostan, in Australia, and New Zealand; in the island of Batavia, and on the eastern coast of China; in Melville island; in Nova Scotia; in the States of North America; and on the coasts of Chili.

203. *The physical aspect of carboniferous districts* is rather tame and unprepossessing. The hills connected with the mountain limestones sometimes present considerable variety of scenery, owing to the bold escarpments of that rock, its extensive fissures and caverns, and the irregular undulations of the trap. These features are also aided by the general verdure and fertility of limestone districts, which present a freshness and luxuriance peculiar to themselves. The coal districts are almost always tame and unattractive, relieved by few elevations or depressions of picturesque beauty, and being, in general, bleak and unfertile from the cold and retentive nature of the soil. Occasionally, a basaltic crag or isolated trap-hill relieves the monotony; but this is the exception to the general rule.

204. *The economical value of the carboniferous system* fully compensates for any deficiency in the fertility of its soil, or in the picturesque beauty of its geographical features. *Building-stone* of the finest quality (of which that of Craigleith, near Edinburgh, and of Calelo in Fife, are good examples) are obtained from the sandstones beneath the mountain limestone; while the millstone grit and flaggy beds of the coal measures yield other valuable freestones. Of all the limestones in the crust of the earth, the *Mountain* is that which is most valuable and abundant; and from it are principally derived those stores of *lime* so indispensable to the purposes of the builder,

agriculturist, iron-founder, &c. Where the encrinal beds are sufficiently hard and crystalline, they furnish a very prettily-marked *marble;* the joints, stalks, plates, and star-like tubes of the corals shining out from the darker matrix in which they are imbedded. Many ornamental *spars* (Derbyshire spar) are found in the veins of the mountain limestone, which are also the principal sources of *lead ore* in the British islands; Derbyshire, Alston Moor in Cumberland, and Lead Hills in Lanarkshire, being well-known lead-mining districts. *Silver* and *gold* are both more or less associated with the ores of lead, especially the former; but they are seldom sought after, unless in connexion with lead. *Fire-clay* is dug up from the coal measures for the making of fire-bricks, furnace linings, &c.; *ochre* (hydrated oxide of iron), which occurs in several coal-fields, is extensively used as a pigment; and *alum* (sulphate of alumina) is obtained from many of the pyritous shales of Germany. *Ironstone*, which is found in the coal-shales either in bands, nodules, or septaria, is one of the most valuable products of the carboniferous system. It is obtained in great abundance, and being easily reduced to a metallic form by the application of coal and lime, in which the system abounds, it may be said to form one of the prime elements of our country's mechanical and commercial greatness. About two millions of tons are annually manufactured in Britain for the fabrication of the innumerable machines, utensils, and implements to which cast-iron, malleable-iron, and steel, are respectively applied. But notwithstanding the great value of these rocks and



without foundation. However, calculating the amount of unwrought coal in South Wales, in the middle and northern districts of England, and in the Lowlands of Scotland, and making allowance for more perfect systems of mining, and more economical modes of burning, it is estimated that, at the present rate of consumption, there is coal sufficient to meet the demand for 2000 years.

EXPLANATORY NOTE.

CARBONIFEROUS (Lat., *carbo*, coal, and *fero*, I bear)—coal-bearing or coal-yielding; applied to that system of strata from which the chief supplies of coal are obtained.

SUB-CRYSTALLINE—less than crystalline, or not distinctly crystallised. In geology, the prefix *sub* is often used in this sense; thus we say *columnar* basalt, when the columns are distinct and regular in shape, and *sub-columnar*, when the mass presents traces of an irregular columnar structure.

ENCRINITES.—In many instances, the calcareous matter of the encrinite has been dissolved, so as to leave a screw-like cast of the imperforation and jointings. These casts are known by the vernacular names of *screw-stones* and *pulley-stones;* just as turbinoliæ (fig. 2, p. 87) are called by quarrymen *pipe-heads*, and the smaller stalks of encrinites *pipe-shanks* or tubes. Separate pieces of the stalks are known in the north of England as *St Cuthbert's beads*, from a legend alluded to by Sir Walter Scott in the following lines:—

> ———On a rock, by Lindisfarne,
> St Cuthbert sits, and toils to frame
> The sea-born beads which bear his name.

From the wheel-like shape of the pieces which compose the stem of the encrinite, they are sometimes technically termed *entrochi* (*trochus*, (wheel) a wheel), and the limestone through which they are scattered *entrochal limestone*. This term, however, is principally applied to the pieces of the minutest stems.

LIMESTONE CAVERNS.—Caves and fissures present themselves in all rocks which have been subjected to the influence of subterranean movements, or to the eroding power of water; and may thus occur either in igneous rock, as Fingal's Cave in Staffa, or in sandstone, as the caverns of Arbroath. It is, however, in limestone that the most celebrated caves and grottos are to be found; indiscriminately in the mountain, magnesian, or oolitic beds, but on a scale of far greater splendour and magnificence in the former. Those of Derbyshire, Mitchelston in Ireland, Paros and Antiparos in the Archipelago, Australia, &c. are examples of this class, and have been formed partly from fissures caused by igneous movements, and partly by the eroding influence of springs and subterranean streams. The joints and divisional planes which so numerously intersect the mountain limestone, no doubt greatly facilitate these excavating operations.

ANTHRACITE (Gr., *anthrax*, coal)—a variety of coal almost wholly deprived of its bitumen. It may be regarded as a natural charcoal formed by subterranean or by chemical heat. Common bituminous

diamonds is comparatively of recent origin, & scarcely anterior to the destruction of Mammoths. See postea p. 224, &c.
The specific gravity of coal is, 1 to 1.5; that of diamond is 3.5.

coal is often found converted into anthracite by effusions of igneous rock; and this fact suggests the idea that all deposits of the kind have been similarly produced. The most extensive fields of anthracite are in Pennsylvania and the bordering states of North America.

BITUMENS OF THE CARBONIFEROUS SYSTEM.—Besides the many varieties of coal, which are bitumens mingled more or less with earthy impurities, there are other bituminous substances derived from the system. Naphtha, petroleum, mineral pitch, and asphalte, ooze out by rents; mineral caoutchouc (*elaterite*, or elastic mineral pitch) is found in crevices of the limestone; and a number of mineral resins and fats —such as common mineral resin, sphero-resinite (globular drops of mineral resin), mellite (crystallised resin or honeystone), Hatchetine, (mineral tallow), &c.—are obtained in small quantities. Carburetted hydrogen (fire-damp) and carbonic acid gas (choke-damp), both so fatal to miners, seem to be evolved from the coal beds after the same manner as several of the above-named products.

COPROLITES (petrified excrements) are found in all the systems of the secondary and tertiary epochs. They are chiefly the voidings of fishes and sauroid animals, and yield unequivocal evidences of their origin in containing scales, bones, and other fragments of the creatures on which these voracious animals preyed. Many specimens of coprolite retain on their external surfaces the convolutions and corrugations of the intestines; and masses of it have been found *in situ* within the ribs of ichthyosauri.

NEW RED SANDSTONE SYSTEM.

205. *After the deposition and upheaval of the carboniferous system*, a new era occurs in the history of the globe. Overlying the coal measures in some places conformably and in

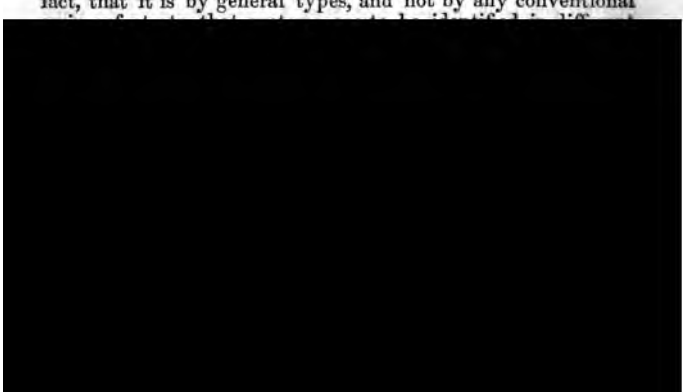
stones of various fineness, from a hard quartzose grit to a brecciated conglomerate. Few of them are laminated or micaceous, and the thicker beds often present curious spherical concretions of a harder texture, containing some foreign substance as a nucleus. The grains of the sandstones are of a clear quartz, merely coloured externally by a coating of the red oxide of iron, as if the debris of the rocks from which they were derived had been deposited in ferruginous waters. The *argillaceous* members are usually called "marls," from the fact of their often containing a little calcareous matter, and being less laminated in structure than the coal shales. They are generally red; but are sometimes mottled purple, yellow, and green (called variegated marls), and contain irregular beds and plates of gypsum (sulphate of lime). The *calcareous* members vary from an almost pure carbonate of lime to an admixture of carbonate of lime and carbonate of magnesia —thence called *Magnesian Limestone.* They vary in colour from an ash-gray to a cream-yellow; are sometimes finely laminated; at other times granular and crystalline, and in this state called *dolomite*, after M. Dolomieu. Frequently, a layer exhibits a cellular or vesicular texture, the walls of the cells being sparry, and the cells themselves filled with loose powdery limestone. This cellular structure is abundant in the magnesian limestone of Durham, and has received various terms from the shape of the cells; as *honeycombed; botryoidal,* composed of little spherical concretions like a bunch of grapes; and *mammillary,* when the concretions assume an elongated or pap-like shape. These concretionary and cellular forms are said to be *coralloidal*—that is, like to corals in shape; but they have nothing to do with organic structure, being merely the result of chemical or mechanical aggregation. The *saline* members are chiefly rock-salt, which occurs in white crystallised masses, or reddened by the argillaceous sediment among which it occurs. Salt springs abound in the new red sandstone, partly from the shales being all more or less impregnated with salt, and partly from the decomposition of the rock-salt itself. Gypsum occurs among the marls either in films or foliated fragments, the latter variety being the *selenite* of mineralogists; and oxide of copper is the green colouring matter of the shales.

207. *The order of succession among the members* of the new red sandstone is not very regular or persistent. In England, the lower part of the series consists chiefly of red sandstones and grits, the middle of magnesian limestones and gypseous marls, and the upper portion of variegated sandstones and marls, enclosing local deposits of gypsum and rock-salt. On

account of this triple succession, Professor Sedgwick has divided the system into the following groups :—

Groups.	*Description.*
UPPER.	7. VARIEGATED MARLS—red, with bluish, greenish, and whitish laminated clays, or marls holding *gypsum* generally, and *rock-salt* partially (as in Cheshire). Included in these marls are certain beds of gray and whitish sandstones.
	6. VARIEGATED SANDSTONES—red sandstones with white and mottled portions, the lower parts in some districts pebbly.
MIDDLE.	5. LAMINATED LIMESTONES of Knottingley, Doncaster, &c. with layers of coloured marls.
	4. GYPSEOUS MARLS—red, bluish, and mottled.
	3. MAGNESIAN LIMESTONE—yellow and white ; of various texture and structure ; some parts full of fragmentary masses.
	2. MARL SLATES—laminated ; impure calcareous rocks of a soft argillaceous or sandy nature.
LOWER.	1. RED SANDSTONE—with red and purple marls, and a few micaceous beds. The grits are sometimes white, or yellow ; and pebbly. When conformable, this sandstone occasionally passes into the coal measures on which it rests.

It must not be supposed, however, that the system always forms so complete a section ; for in some places the gypseous marls predominate, in others the magnesian limestone, while in several a mass of redstones, with subordinate layers of coloured shales, represent the whole system. The following table shows how the deposit occurs in Germany, England, and France ; from which the student may also learn the important fact, that it is by general types, and not by any conventional



fossil plants, shells, fishes, and reptiles of this system, appear to partake both of the character of those in the older carboniferous, and the newer oolite deposits. Calamites, like those of the coal formation, are mingled with cycadeæ, resembling closely those of the oolites. Productæ, so common in mountain limestone, occur in the zechstein with terebratulæ, like those of the lias and oolites. Fishes of the genus palæoniscus here occur for the last time, in ascending the series of strata; and here, perhaps, for the first time we have remains of oviparous quadrupeds—the protosaurus and phytosaurus." Exhibiting this transition from one system of life to that of another, the new red sandstone has been regarded as the boundary between the LOWER and UPPER SECONDARY STRATA—the old red sandstone, mountain limestone, coal measures, and new red sandstone, belong to the *lower* or older secondary formation; and the lias, oolite, and chalk, to the *upper* or younger secondary.

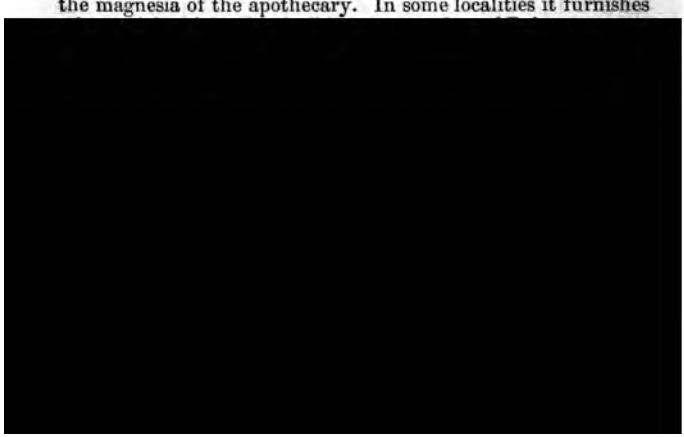
209. *The number of fossil species* hitherto detected in the new red sandstone of England amounts to fifty or thereby, while fully thrice that number has been found in France and Germany. These consist of traces of marine plants, a few terrestrial plants, several zoophytes, one species of crinoidea, about two dozen species of bivalves, one chambered shell, several fishes, the mutilated skeletons of two sauroid animals, and the traces of footsteps, called *ichnites*, from the Greek *ichnon*, a footmark. Like the vegetation of the coal era, the plants of the new red sandstone are chiefly vascular cryptogamia; the corals, bivalves, and fishes, are apparently the same; and it is only in the chambered shells, and in the sauroids, that new types are presented. Altogether, the system seems to have been deposited under circumstances peculiarly unfavourable to animal and vegetable life; at least few organic exuviæ are to be met with in its strata.

210. *The igneous rocks associated with the system* are chiefly dykes of greenstone, which pass indiscriminately through the magnesian limestone, coal measures, and old red sandstone. These dykes belong to no definite volcanic era, but seem to have been formed by minor forces acting over limited extents. The granitic rocks of the primary period, as well as the traps of the old red sandstone and carboniferous measures, establish themselves in well-marked and characteristic ranges; while the igneous rocks of the new red sandstone, lias, and oolite, are mere local effusions limited to dykes and partial upheaves. In their mineral character, these rocks differ little from the traps of the coal measures—consisting chiefly of greenstone, pitchstone, and clay-stone porphyry.

211. *The extent of country* over which this system is spread is not well ascertained. Slight traces of it occur on the western coast and islands of Scotland, and on the Fife shores of the Forth; it occupies a wider area in the basin of the Solway and its tributaries; spreads largely over the central districts of England from the Tyne southwards; and is found in the north of Ireland. Extensive areas are covered by it in the continent of Europe—in France, Germany, Poland, along the flanks of the Alps, in Austria, and between the Volga and the Ural mountains; and, according to Professor Hitchcock, it is spread over considerable spaces in some of the river valleys of the United States.

212. *The physical aspect of new red sandstone districts*, as may be conjectured from the limited force of the igneous rocks, is rather flat and gentle. There are no picturesque crags, mountain ranges, or deep ravines to diversify the scenery; which consists of rounded terraces of magnesian limestone, and level expanses of red sandstone and shales, here and there dotted with a gentle eminence of limestone or gravel. Over the limestone the sward is thick and verdant, and the soil above the red sandstone is of average fertility; but where the retentive shales spread out in flat hollows, they form the basis of extensive morasses—as, for example, those of south Lancashire, in England.

213. *The minerals of commerce derived from the formation* are not numerous—the most important being magnesia and rock-salt. The magnesian limestone, when reduced to quicklime, is employed with effect on certain soils; it furnishes the builder with mortar; and yields, under chemical treatment, the magnesia of the apothecary. In some localities it furnishes



masses by subterranean waters. The *kupfer-schiefer* of Germany is worked to some extent as an ore of copper; but no other metal is derived from the system.

214. *The formation of rock-salt* is a subject, in connexion with this system, which has much engaged the attention of speculative geologists. The sandstone and marls with which it is associated are evidently derived from deposition in water; but the irregularity of the salt beds, the fact of their occurring in masses of vast thickness, and the soluble nature of the compound, all point to a somewhat different origin. At present, salt lakes and superficial accumulations of salt occur in various parts of the world, and these have furnished data for reasoning as to the saliferous deposits of earlier eras. Salt lakes are chiefly derived from salt springs, and being subjected to the vaporising influence of the sun, which carries off only *fresh* vapour, their waters become in time saturated with saline matter. But water can hold only a fixed amount of salt in solution; and so soon as this amount is attained, the salt begins to fall to the bottom by its own gravity. In the course of ages, these layers will form a thick bed, interstratified, it may be, with mud, or other earthy sediment; and if the lake should be ultimately dried up, the salt will constitute a deposit something analogous to the rock-salt of the new red sandstone. Such is the process which some geologists have advanced to account for the formation of rock-salt—supposing that portions of the seas of deposit were occasionally cut off from connexion with the main ocean, and subjected to a rapid evaporating power, without receiving fresh accessions of water. The limited extent of rock-salt basins seems to favour such a theory; but when we consider the frequency of disturbance by volcanic forces in earlier ages, and the fact of many of these deposits occurring near to, or in connexion with, mountain elevations, it is more than probable that igneous action, as well as a high atmospheric temperature, had to do with their formation. If such were the origin of rock-salt, it must have been formed during the deposition of other systems than the new red sandstone; and this geological research has confirmed; for although the most extensive accumulations do occur amid the sandstones and shales of the system under review, still, deposits of considerable thickness are found in connexion with oolite, green-sand, and tertiary rocks, while numerous salt springs issue from the carboniferous strata.

215. *The formation of magnesian limestone* has also given rise to several theories. Minute quantities of magnesia occur variously combined in the crust of the earth; but only in the limestones of this system is it sufficiently developed to consti-

tute a peculiar and distinguishing feature. The most prevalent hypotheses advanced to account for this peculiarity are —first, that the carbonate of magnesia was deposited at the same time as the carbonate of lime; and, second, that it was subsequently injected in the form of gaseous vapour. Neither hypothesis seems to account for all the phenomena presented; although the former is that which admits of most extensive application.

NEW RED SANDSTONE SYSTEM.—In some recent works, it has been attempted to arrange the rocks of this system, as developed in England, under two grand divisions; the first including the lower new red sandstone and magnesian limestone, and the second the variegated sandstones and gypseous marls. This arrangement has been made in order to facilitate comparison with the contemporaneous systems of continental and eastern Europe. In Germany and the neighbouring countries the former division corresponds with the *Rothe-todte-liegende*, and the latter with what is now generally known as the *Triassic* system (so called from its being readily divisible into three groups—the Bunter Sandstein, Muschelkalk, and Keuper Marls). To the rocks of eastern Europe, which seem contemporaneous with the new red sandstone, Mr Murchison has applied the term *Permian system*, from their being widely developed in the ancient kingdom of Permia, which extends for several hundred miles along the western flanks of the Uralian chain, and thence westward to the river Volga.

ZECHSTEIN (mine-stone)—so called from its containing a deposit (*Kupfer-schiefer*, or copper-slate) which is worked as an ore of copper; and the underlying sandstone has received the name *Rothe-todte-liegende* (red dead-lier), because it is of a red colour, is *dead* or worthless as far as any metallic ore is concerned, and *underlies* the real metallic

[redacted]

OOLITIC SYSTEM.

LIAS, OOLITE, AND WEALDEN GROUPS.

216. *After the deposition of the new red sandstone*, a further change was effected upon the general conditions of the globe, so as to produce not only an entirely different set of strata, but also different races of plants and animals. In most districts, the red sandstones and magnesian limestone were upheaved, to form new land, while portions of the former dry land were submerged beneath the ocean. By this process of elevation and depression the courses of previous rivers would be altered, former seas circumscribed and rendered more shallow, plants and animals subjected to a new distribution, and thus a different set of deposits would necessarily ensue. Instead of magnesian rocks, we have dark argillaceous and oolitic limestones; for variegated saliferous marls, we have blue pyritous clays; and instead of red and mottled sandstones, yellow calcareous grits. All this points to a new epoch in the terrestrial conditions of the world; and to the system of strata thus deposited geologists apply the term *oolitic* (Gr., *oon*, an egg, and *lithos*, a stone), from the resemblance which the texture of many of the beds bear to the roe or eggs of a fish. Oolite, or *roestone*, is an aggregate of rounded calcareous particles, varying from the size of a millet-seed to that of a marble—the smaller being almost perfectly spherical, the larger irregular, and having their interstices filled with calcareous matter or broken shells. The system in England comprises three well-defined groups; namely, the Lias, the Oolite proper, and the Wealden clays.

217. *The Lias*, the lowest group in the system, is composed of dark argillaceous limestones, bluish clays, and shales. The clays in general predominate, and occur with interstratified limestones; they contain occasional layers of jet or other coal: ironstone in septaria is not unfrequent; and many of the shales abound in bitumen and iron pyrites. As indicated by the name (*lias*, corruption of *layers*), the limestones are finely stratified, and have evidently been deposited in tranquil waters. Most of the shales, in addition to their bituminous and pyritous qualities, are impregnated with muriate of soda (common salt), and with the sulphates of magnesia and soda: and Mr Bakewell states that it is not uncommon, after wet weather, for the Yorkshire sea-cliffs, which are composed of these shales, to ignite spontaneously, and burn for several

months. *The Oolite* is more varied in its composition, consisting of oolite limestones, calcareous grits, or conglomerates, yellowish sands, and clays all more or less calcareous. The peculiar rounded grains which constitute the oolitic texture, consist either entirely of lime, or of an external coating of lime, collected round minute particles of sand, coral, shells, &c.; the grits are composed of sand, lime, fragments of shells and corals; and many of the clays present the same brecciated texture. *The Wealden group* (from the *wealds* or *wolds* of Kent and Sussex, where the deposit prevails) consists of beds of bluish clay, argillaceous limestones, impure oolites, and ferruginous sandstones. Nodular ironstone occurs in the clays, and beds of pisiform (Lat., *pisum*, a pea) iron-sand are occasionally met with, while oxide of iron is more or less diffused through the whole group. Fossil plants are abundant; and, as may be expected from this circumstance, local traces of coal are not unfrequent.

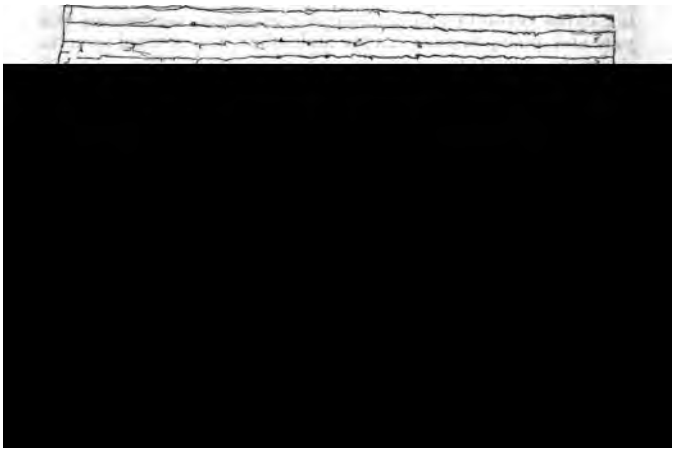
218. *Taking the whole system into account*, it is apparent that calcareous and argillaceous compounds prevail; indeed it may be said to be an argillo-calcareous deposit, including subordinate layers of sandstone, bands of ironstone, and traces of coal. Among the lias strata, dark hues prevail; among the oolite, cream-yellow and ochraceous colours; the clays of the wealden are dark blue, while its other beds partake of a ferruginous tint.

219. *With regard to the succession among the strata*, no very regular order is observed; though no fact in geology is better established than the supraposition of the lias, oolite, and wealden, as above-described. The lias is the most extensive and persistent of the three groups, and seems to have been

OOLITE.	Portland oolite; calcareous irony sand and concretions; and a calcareous clay, locally called "Kimmeridge clay." Coralline oolite (coral rag); calcareous sands and grits; Oxford clay, including layers of impure clayey limestone. Oolitic and shelly strata (Cornbrash); forest marble; Bath oolite; yellow sandstones, divided by clays and calcareous sands; marls and fuller's earth.
LIAS.	Thick beds of dark-coloured bituminous shale; beds of pyritous clay; and indurated lias marls. Lias limestones and clays; bands of ironstone; layers of jet and lignite; sandstones more or less calcareous.

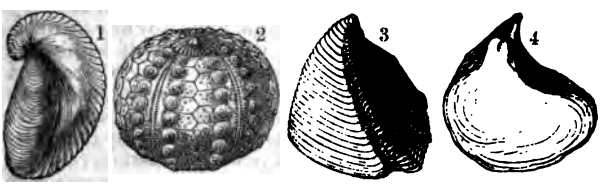
220. *The organic remains of the oolitic system* are very numerous, and have long attracted the attention of geologists. They show a decided advance upon pre-existing races, inasmuch as insects, amphibious reptiles, and mammalia, make their appearance in the animal kingdom; while new tribes of vegetables, such as the cycadeæ, lilaceæ, &c. are added to the former Flora. The organisms of the lias, the oolite, and the lower members of the wealden, indicate the marine origin of these deposits; those of the upper weald an estuary character, from the comminglement of fresh water with marine species. With this distinction, the Fauna and Flora of this epoch may be thus summarily detailed:—*Plants*—seaweeds; a few equisetums; many ferns allied to the sphenopteris, pecopteris, &c. of the coal measures; cycadeæ, allied to the existing cycas revoluta and pine-apple; coniferæ, resembling the yew and pine; besides lilaceæ and other undescribed genera. *Animals*—zoophytes, more like existing species than those of the mountain limestone and silurian rocks; crinoidea, chiefly the apiocrinite and pentacrinite; star-fishes, resembling the common ophiura and asterias; echinida (sea-urchins), of which the cidaris is one of the most beautiful and abundant; shell-fish, both bivalves, univalves, and chambered; annulosa, like the common serpula and land-worm; crustacea, resembling the lobster-tribe; insects like the beetle and dragon-fly; fishes belonging chiefly to the ganoidia; reptiles allied to the tortoise, to the crocodile, and gavial of existing rivers, but differing widely in their external forms and modes of existence; mammalia, two or three specimens of small marsupial animals allied to the oppossums. In the upper or fresh-water wealden, there are no zoophytes or marine mollusca; but there are, according to Phillips, various land plants, fresh-water bivalves and univalves, some fishes, sauroid animals, and remains of turtles, both fresh-water and marine.

221. *The fossils most characteristic of the system* are the cycadeæ, of which the stems, fruit, and leaves are found in abundance, the sea-urchins, the ammonites of various genera and gigantic size, the sauroid reptiles, the ptero-dactyles or flying lizards, the fresh-water and marine turtles, and the marsupial mammalia. The cycadeæ occur principally in the upper or fresh-water portion of the weald, intermingled with the stumps and prostrate trunks of trees. They are found most plentifully in what is locally designated the "dirt-bed" of Portland—a stratum of dark argillaceous mud, which must at one time have been the soil in which they and other vegetables flourished, but which, by a submergence of the land, was converted into the bottom of an estuary, over which other strata of clay, limestone, and sand were deposited. "At the distance of two feet," says Bakewell, "we find an entire change from marine strata to strata once supporting terrestrial plants; and should any doubt arise respecting the original place and position of these plants, there is, over the lower dirt-bed, a stratum of fresh-water limestone, and upon this a thicker dirt-bed, containing not only the cycadeæ, but stumps of trees from three to seven feet in height, in an erect position, with their roots extending beneath them. Stems of trees are found prostrate upon the same stratum; some of them are from twenty to twenty-five feet in length, and from one to two feet in diameter. The following section of a cliff in Dorset exhibits very clearly proofs of the alternation from



marine strata to dry land covered with a forest, and of a subsequent submergence of the dry land under a river or lake which deposited fresh-water limestone."

222. *Of the radiata, mollusca, and crustacea of this era*, it may be observed, that while they differ essentially from those of the older secondary strata, they approximate in form to existing races. The gigantic and prolific crinoidea of the mountain limestone had disappeared, and been succeeded by a few dwarfish specimens of apiocrinite and pentacrinite; while the cidaris (see fig.), clypeus, and other echinida (sea-urchins), attest a higher degree of organisation among radiated animals. Among the shell-fish, the *gryphæa*, *trigonia*, *ostrea*, and *ammonite*, are the most characteristic—hundreds of species of



1. Gryphæa incurva; 2. Cidaris intermedia; 3. Trigonia costata; 4. Ostrea deltoidea.

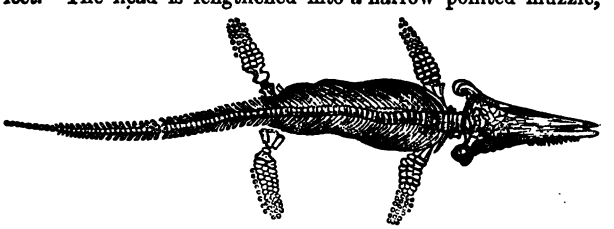
the latter having left their remains in the most perfect state of preservation in the shales and limestones of the lias. The ammonite (of which two species, and a section of the interior, is figured below) receives its name from its resemblance to the curved horn on the head of the statue of Jupiter Ammon. It

1. Ammonites obtusus; 2. Section of Ammonites obtusus, showing the interior chambers and siphuncle; 3. Ammonites nodosus.

was a chambered shell belonging to the *cephalapodous* division of mollusca—that is, having its organs of motion arranged round the head; and had many congeners in the euomphalus,

nautilus, orthoceratite, hamite (hook-shaped), scaphite (boat-shaped), baculite (staff-shaped), and other many-chambered shells. It is one of the most widely-distributed molluscs in the secondary strata, and is found of all sizes, from that of a pin's head to three or four feet in diameter. The economy of the ammonite destined it in general to live at the bottom of deep waters, but to be able to rise at pleasure to the surface. For this purpose the outer chamber (*o o*) of the wreathed shell was fitted for the reception of the animal, while the interior chambers (*i i*) were hollow, so as to make the whole structure nearly of the same weight as the element in which it moved. Through all of these chambers an elastic tube passed by means of a pipe or siphuncle (*s s*), the tube being in connexion with the cavity of the heart, which, under ordinary circumstances, was filled with a dense fluid. When alarmed, or wishing to descend, the animal withdrew itself within the outer chamber, and the pressure upon the cavity of the heart forced the fluid into the siphuncle, so as to increase the gravity of the shell, by which means it readily sunk to the bottom. On the other hand, when wishing to ascend, it had only to project its arms, and the fluid, being freed from the pressure, returned from the siphuncle to the cavity of the heart, thus restoring the whole structure to its ordinary floating gravity. As the pressure of water at the bottom of the sea would break the plates of any ordinary shell, as it does a bottle when it is lowered to a great depth, the shell of the ammonite has been strengthened by a curious kind of internal arch-work, so as to be able to resist the weight of the incumbent fluid. This

above it, the exuviæ of these animals are so abundant, and of such vast size, that the epoch in which these strata were deposited has not unaptly been termed "the age of reptiles." Of these there are terrestrial and marine chelonida (tortoises and turtles); lizards, whose arms and legs were fitted with a filmy membrane, like bats, to enable them to fly (pterodactyles); amphibious saurians, like the gavial and crocodile; and water saurians, to which there is now no existing analogy. Of these sauroid or lizard-shaped reptiles, the ichthyosaurus and plesiosaurus are most abundantly disseminated through the upper secondary formations. The general form of the ichthyosaurus (Gr., *ichthys*, a fish, and *saurus*, a lizard) appears from its skeleton (see fig.) to have been not unlike that of a crocodile, with the substitution of paddles for feet. The head is lengthened into a narrow pointed muzzle,



Skeleton of Ichthyosaurus communis.

and the jaws armed with sharp and formidable teeth. The skeleton of the *I. tenuirostris* (slender-muzzle) usually measures about four feet in length; but detached remains of other species have been found, indicating a length of twenty or even thirty feet. The plesiosaurus (so called from its greater affinity to the lizard tribe than to fishes) was distinguished by the extraordinary length of its neck, which, in the commonest species (*P. dolichodeirus*, or long-necked), occupies nearly half the entire length of the animal. The head is very small in proportion, and the tail is short, stout, and pointed. The vertebræ of the neck exceed in number those of any other animal known.† It is conjectured by Mr Conybeare, by whom the first scientific investigation of this saurian was made, that, as it breathed air, and had frequent need of respiration, it generally swam upon or near the surface of the water, arching back its long neck like the swan, and plunging it downwards at the fishes that passed within its reach. Its length seems to have been from ten to fifteen feet. From the nature of their extremities, both the ichthyosaurus and plesio-

† Teeth found in the lower jaw of a *P. d* = 54 [illegible] in both jaws.

saurus must have moved with great difficulty upon land, and seem principally to have inhabited the waters. Besides these, geologists enumerate many other species of saurians—aquatic, amphibious, and terrestrial; such as the *megalosaurus* (great saurian), *geosaurus* (land saurian), *hylaeosaurus* (forest saurian), *teleosaurus* (perfect saurian), &c.

224. *Respecting the mammalia of this era*, no very satisfactory data have yet been procured, the only evidence being two or three lower jaw-bones from the slaty limestone of Stonesfield. Though some French geologists have attempted to ascribe a sauroid character to these remains, it is the opinion of Cuvier, Dr Buckland, and Professor Owen, that they belong to true *didelphys* (*dis*, two, *delphys*, wombs) animals; that is, double-wombed, or marsupial creatures, like the opossum and kangaroo. Should this be the case—and comparative anatomy is too unerring in its deductions to admit of any doubt—then in the upper oolite are we for the first time made acquainted with mammalia in the history of creation. "The close approximation of these fossil animals," says Professor Owen, "to marsupial genera, now confined to New South Wales and Van Diemen's Land, leads us to reflect upon the interesting correspondence between other organic remains of the British oolite, and other existing forms now confined to the Australian continent and adjoining seas. Here, for example, swims the *cestracion*, which has given the key to the nature of the palates from our oolite, now recognised as the *teeth* of congeneric gigantic forms of cartilaginous fishes. Not only *trigoniæ*, but living *terebratulæ* exist, and the latter abundantly in the Australian seas, yielding food to the cestracion, as their extinct analogues doubtless did to the allied cartilagi-

among which the flying lizard (pterodactylus) spread his filmy wings. The rivers and shores were watched by saurians more or less amphibious (megalosaurus, iguanodon), or tenanted by reptiles which by imaginative men have been thought to be the originals of our gavials and crocodiles, while the sea was full of forms of zoophyta, mollusca, articulosa, and fishes. Undoubtedly the general impression, gathered from a survey of all those monuments of earlier creations, is, that they lived in a warm climate; and we might wonder that the result of all inquiry has shown no trace of man or his works, did we not clearly perceive the oolitic fossils to be all very distinct from existing types, and combined in such different proportions, as to prove that circumstances then prevailed on the globe materially different from what we now see, and probably incompatible with the existence of those plants and animals which belong to the creation whereof man is the appointed head."

226. *The igneous rocks associated with the system* in England belong chiefly to the trappean order. In no case have they caused much displacement or great disturbance among the strata, being gentle outbursts of trap-tuff, or intersecting dykes of greenstone. These dykes are always connected with some volcanic axis of the carboniferous period, and seem to have been among the last upheaving efforts of the trappean era. In Caithness, granitic rocks pass through the oolitic strata, but with this exception—the igneous rocks, which have upheaved or altered the system, belong either to the latest trap, or the earliest volcanic epochs.

227. *The extent of country occupied by the oolite* is by no means extensive, though partial deposits are very generally disseminated over the globe. It is most fully developed in England, occupying the eastern sea-board from Yorkshire to Dorset; it occurs in a small patch at Brora in Sutherland, in Skye, and other of the Hebrides, and partially in Ireland and Wales. Portions of the system are also found in France and Germany; skirting the Alps; in Spain and the Balearic islands; flanking the Apennines and Atlas range; on the southern slope of the Himmalehs; but no true equivalents to the European oolite have hitherto been detected in America.

228. *Unless in England, the oolitic system is not so extensively developed as to impart any distinctive geographical feature;* and there, though pleasing, the aspect is tame compared with that imparted by the older strata. The limestones in general form rounded escarpments over the subjacent clays, "so that several longitudinal hollows and ridges undulate the area occupied by the system." None of these ridges are of great

height (400 to 600 feet), but they are dry and fertile; and thus present an agreeable contrast with the level river valleys occupied by the lias and wealden clays.

229. *In an economical point of view*, the rocks of this system are by no means unimportant. The lias limestones generally consist of from 80 to 90 per cent. of carbonate of lime, combined with bitumen, alumine, and iron; and when the latter mineral enters largely into their composition, they form, when burned, a lime which has the property of setting under water. The finer kinds of lias receive a polish, and are used for lithographic purposes. The lias clays are often much impregnated with bitumen and iron pyrites, and will burn slowly when laid in heaps with fagots and kindled. By this process the sulphur of the pyrites is decomposed, and combining with the oxygen of the atmosphere, and with a portion of the alumina in the shale, forms sulphate of alumina, or the *alum* of commerce. During the sulphur monopoly, several patents were obtained for the extraction of sulphur from iron pyrites (sulphuret of iron), most of which would have been profitably adopted, had the native produce of Sicily continued at the then exorbitant rate. Iron has also been extracted from the ironstone and pisiform iron-sands of the wealden group; and jet (which is simply altered coniferous wood) occurs in the same measures. Fuller's earth, at one time so valuable in the useful arts, is found in the upper oolite in beds of great thickness. It is essentially composed of silica, alumina, and 24 per cent. of water, and, like other soft aluminous marls, possesses in a high degree the power of absorbing grease; hence its value in cleansing and scouring woollen stuffs. Some of the oolite sandstones form excellent building material, such

THE CHAMBERED SHELLS of this system include many genera, all of which are fitted with interior hollow chambers and siphuncles. The most common are the ammonite, nautilus, euomphalus, bellerophon, goniatite, hamite (*hamus*, a hook), scaphite (*scapha*, a boat), orthoceratite (*orthos*, straight, *keras*, a horn), baculite (*baculum*, a staff), lituite (*lituus*, an augur's rod or crosier), &c. &c. Sometimes the shelly matter of the ammonite has been entirely destroyed, leaving only a cast of the interior, each chamber in this case playing upon another by the intricate jointings of the *septa*, or divisional lines; such casts are known by the name of *ammonites catena*, or ammonite chains.

CRETACEOUS, OR CHALK SYSTEM.

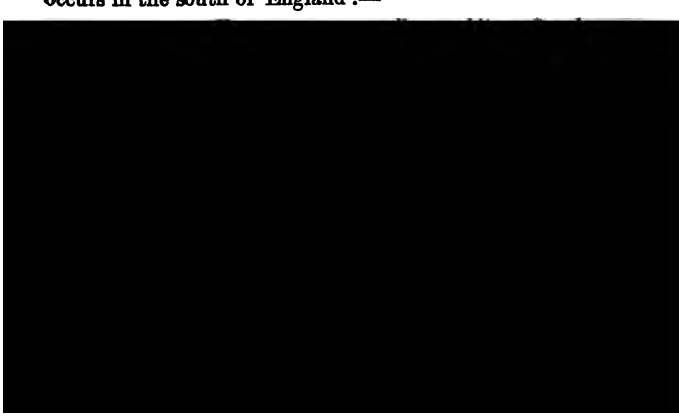
See Allen - 1851, p. 1359

230. *Immediately overlying the wealden, and forming the upper portion of the secondary formation*, occurs a set of calcareous, argillaceous, and arenaceous strata, distinguished in Europe as the Cretaceous System, from its containing the well-known mineral, *chalk* (Lat., *creta*). In this system, as stated in par. 140, the arenaceous members are no longer sandstones, but loose unsolidified sands; the argillaceous beds are generally soft and marly clays; and the calcareous, instead of compact or crystalline limestones, present that soft earthy texture which prevails in chalk. All this attests a comparative recentness of formation, apart from great pressure, long-continued chemical action, or the indurating effects of heat. The strata occupy very limited spaces, and being decidedly of marine origin, point more to detached and inland seas as the areas of their deposit, than to the shores or bays of the ocean. Being thus, as it were, a local deposit, and of a thickness not exceeding 800 or 900 feet, the chalk has been more thoroughly explored than any of the older systems, and its fossils more rigidly compared with existing species. Upon investigation, it has been found that it embraces three well-marked groups; namely, the *Green-sand*, the *Gault*, and *Chalk*.

231. *The composition of these groups* is almost sufficiently indicated by their respective terms. The *Green-sand*, which forms the lower division, is so named from its green colour, which it owes to a chloritous silicate of iron. These sands, however, are not uniformly green, but partake of ochraceous and yellow tints; they present various degrees of fineness; and not unfrequently contain cherty bands, irregular deposits of fuller's clay, and ochre. In England, they are usually divided into the Lower and Upper green-sands, because of a bed of soft bluish marly clay which occurs about the middle of the group. Regarding this bed as subordinate, the green-sand is easily distinguished from the rest of the system by its arenaceous composition and greenish hues. The Gault, or

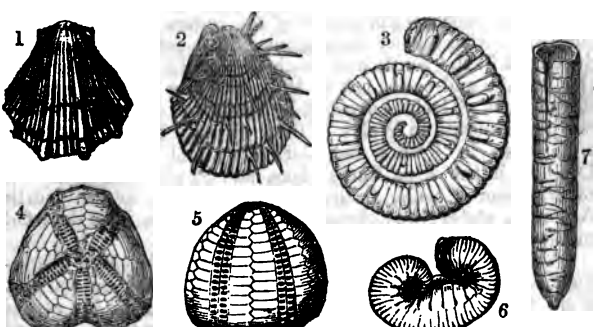
golt (a local term), overlies the green-sand, and is not of great thickness, nor very regular in its occurrence. It is a bluish chalky clay, which effervesces strongly on the application of acids; it is interstratified with layers of green-sand, and holds irregular balls of argillaceous ironstone and iron pyrites. In some districts the gault assumes a reddish tint, from the iron it contains; but in other respects its composition is very persistent. The *Chalk*, which forms the upper group of this system, is too well known to require description. It consists chiefly of carbonate of lime, has an earthy texture, and is so soft as to yield to the nail. Though generally white, it sometimes passes into a dusky gray, or even red colour, as in the north of England; and where it has come in contact with igneous rocks, it is indurated, and of a crystalline texture, like that of statuary marble. In England, the chalk strata average from 600 to 800 feet in thickness, and are usually divided into the lower and upper beds; the former being more compact, of a dusky white varied with green grains, and containing few flints—the latter being a soft white calcareous mass, with chert nodules and regular layers of flints. Traces of stratification are scarcely distinguishable in the mass of the chalk, but are clearly evinced by the lines of flints and other nodular concretions. In some of the continental chalks, carbonate of magnesia prevails to the extent of 8 or 10 per cent., giving to such beds a still more earthy texture.

232. *The order of succession among the strata* is such as has been shown above; but, to render it more distinct, we may transcribe the following sectional detail of the system as it occurs in the south of England:—



All the members detailed above do not occur in other cretaceous districts; for example, there is no green-sand in the north of England; no chalk along the Carpathians; no gault in America; while in South America the system is represented by impure chalky beds of no great thickness.

238. *The organic remains found in the system are eminently marine.* There are very few *plants*, and these chiefly of marine types, such as algæ, confervæ, and other sea-weeds. Rare fragments of ferns, cones of coniferous trees, cycadites, and dicotyledonous wood, have been detected in the green-sand; and a patch of *lignite* is said to occur in the lower chalk, near Rochelle in France. Respecting this deposit, M. Brogniart thinks it may have been formed by the local submergence of a peat moss; but generally speaking, there is no formation so destitute of terrestrial organisms as the chalk. Among the *animal remains*, sponges, corals, star-fishes, annuloss, univalve, bivalve, and chambered mollusca, crustacea, fishes, and reptiles, are found in abundance; but, with one exception, mammalia are not known in the cretaceous rocks. The same races which appeared in the oolite appear also in the chalk, but of very different genera; so much so, that it has been observed that the cretaceous system contains genera never found in any rocks more ancient or more modern. "There



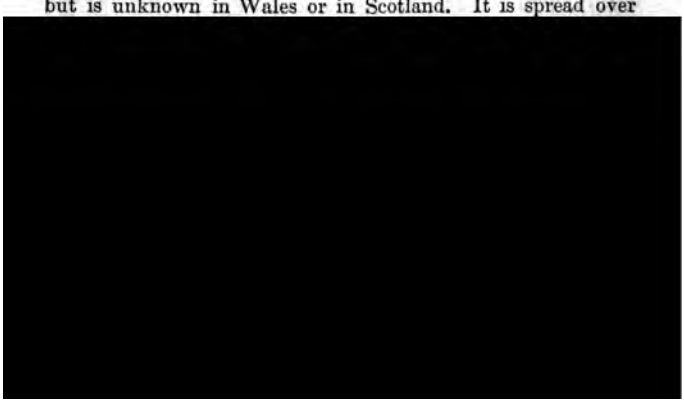
1. Pecten quinque-costatus; 2. Plagiostoma spinosum; 3. Hamites intermedius; 4. Spatangus cor-anguinum; 5. Galerites albogalerus; 6. Scaphites striatus; 7. Belemnites mucronatus.

appears no sufficient evidence," says Professor Phillips, "in the fossils of this system to justify any positive inference as to the character of the climate then prevailing in the northern zones; but we may be sure that the sea was very little dis-

turbed by inundations from the land, otherwise ferns and other plants, and not fuci, would have been found in the sandy strata." It is true that the evidence respecting the climate, and other conditions of the cretaceous era, is still imperfect; but the recently-discovered remains of the highest order of mammalia (quadrumana, or monkey tribe) point to a tropical climate; and this fact, taken in conjunction with the occurrence of cycadites, seems to establish a temperature little different from that which prevailed during the wealden epoch. The foregoing engraving represents a few of the more characteristic fossils belonging to the system.

234. *Igneous rocks* are nowhere associated with the chalk in England; but basalt and other traps break through and overlie the strata in the north of Ireland—the Giant's Causeway presenting one of the finest examples of this connexion. In the Pyrenees, cretaceous strata are said to be in contact with granitic rocks; but, generally speaking, the system has escaped with fewer displacements by igneous agency than any of the earlier formations. As has been stated, where chalk comes in contact with igneous discharges, the heat has rendered it hard and crystalline like primary marble. The same effects have been produced by enclosing pounded chalk in an iron tube, and subjecting it to the heat of a furnace.

235. *The geographical extent of the system* is limited, when compared with earlier formations. It is pretty extensively developed in the south and south-east of England, filling up the hollows and basins left by the oolite and lias. It appears in the north of Ireland overlaid by basalt and other trap rocks; but is unknown in Wales or in Scotland. It is spread over



singular, contain no channel, and but little other circumstantial proof of the action of water, by which they were certainly excavated." Chalk districts thus possess great amenity and rural beauty, and are as yet but little broken up by the enterprise of modern agriculture.

237. *The minerals of commerce* derived from the system are by no means numerous. Chalk is used for many purposes in the arts and in agriculture; it furnishes polishing paste, and the well-known whiting of the painter. Beds of fuller's earth occur in the lower green-sand, and in some districts the more indurated strata of the group produce a rough building-stone. Flint is one of the most valuable products of the system; furnishing material for the manufacture of china and porcelain, flint-glass, and gun-flints—the latter having been in universal use before the invention of the percussion cap.

238. *The formation of flint*, within a mass so different in composition as chalk, is still in some respects an unsolved problem in geology. It occurs in nodular masses of very irregular forms and variable magnitude; some of these not exceeding an inch, others more than a yard in circumference. Although thickly distributed in horizontal layers, they are never in contact with each other, each nodule being completely enveloped by the chalk. Externally, they are composed of a white cherty crust; internally, they are of gray or black silex, and often contain cavities lined with calcedony and crystallised quartz. When taken from the quarry they are brittle and full of moisture, but soon dry, and assume their well-known hard and refractory qualities. Flints, almost without exception, enclose remains of sponges, alcyonia, echinida, and other marine organisms, the structures of which are often preserved in the most delicate and beautiful manner. In some specimens the organism has undergone decomposition, and the space it occupied either left hollow, or partially filled with some sparry incrustation. From these facts, it would seem that flints are as much an aggregation of silex around some organised nucleus, as septaria (par. 192) are aggregations of clay and carbonate of iron. This is now the generally received opinion; and when it is remembered that the organisms must have been deposited when the chalk was in a pulpy state, there can be little difficulty in conceiving how the silex dissolved through the mass would, by chemical affinity, attach itself to the decaying organism. Chalk is composed of carbonate of lime, with traces of clay, silex, and oxide of iron; flint, on the other hand, consists of 98 per cent. of pure silex, with a trace of alumine, oxide of iron, and lime. Silex is quite capable of solution: it occurs in the hot-springs of Ice-

land and most thermal waters; has been found in a pulpy state within basalt; forms the *tabasheer* found in the cavities of the bamboo, and the thin pellicle or outer covering of canes, reeds, grasses, &c.; and siliceous concretions are common in the fruits and trees of the tropics. All these facts point to a very general diffusion of silex in a state of solution; and whatever may have caused its abundance in the waters during the deposition of the upper chalk, there can be little doubt respecting the mode in which it has been collected around the organic remains of these early seas.

EXPLANATORY NOTE.

THE ORIGIN OF CHALK, so different in its texture and appearance from all other limestones, has given rise to many hypotheses. "There appears no evidence," says Mr Brande, "of its having been deposited from chemical solution; but, on the other hand, it bears marks of a mechanical deposit, as if from water loaded with it in fine division. And upon this principle, some gleam of light may perhaps be thrown upon the enigmatical appearance of the flints; for it is found, that if finely-powdered silica be mixed with other earthy bodies, and the whole diffused through water, the grains of silica have, under certain circumstances, a tendency to aggregate into small nodules; and in chalk, some grains of quartz are discoverable." There can be little doubt that such has been the original state of chalk, from whatever source derived; for, without the supposition that the calcareous particles were diffused through the waters in which it was deposited, it were impossible to account for almost any of the phenomena connected with it as a formation. But while such has evidently been the origin of the great mass of the chalk rocks, it does not preclude the chemical agency of springs, or the organic efforts of secreting ani-

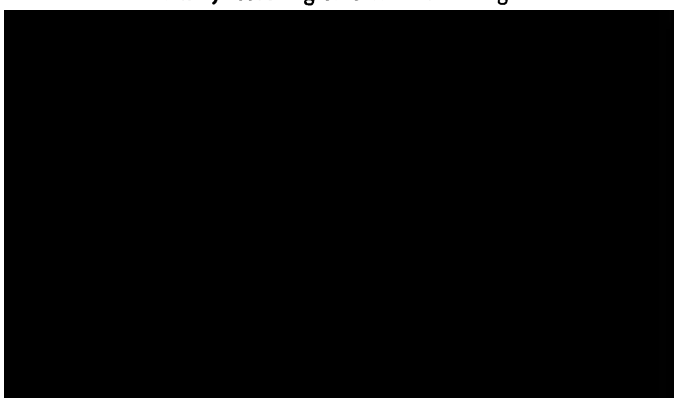
TERTIARY STRATA.

239. THE TERTIARY SYSTEM comprises all the *regular strata* of limestone, marl, clay, sand, and gravel which occur above the chalk. Before the labours of the celebrated Cuvier and M. Brogniart, these beds were regarded as mere superficial accumulations, not referrible to any definite period. Now, however, they are recognised as constituting a distinct formation—differing from the cretaceous not only in its mineral composition, but in the higher order of organisms which it contains, and from the superficial sands and clays, in being regularly stratified, and in imbedding the remains of animals distinct from existing races. In general the strata are loosely aggregated, are of no great thickness, and present appearances which indicate frequent alternations of marine and fresh-water agencies. Thus, marine remains are found in some beds, while others contain exclusively land animals and plants, and fresh-water shells. The whole suit being less consolidated than any of the secondary systems, and containing plants and animals approaching to existing forms, it presents a freshness of aspect which serves to distinguish it from older deposits; at the same time the regularity of its deposition prevents it from being mistaken for any mere alluvial accumulation. In general it occupies very limited and detached areas, as if it had been formed in shallow inland seas and estuaries, to which the waters of the ocean at times had access, and where at other periods fresh-water inundations prevailed. Another essential difference between the tertiary and the more ancient formations consists in the fact, that the latter maintain a wonderful uniformity in their composition and character all over the globe; whereas the former present almost as many distinctions in composition as there are areas of deposit. For this reason it is impossible to give a description applicable to all tertiary strata; those of England and France, however, may be taken as types sufficiently characteristic.

240. *Respecting the composition of the system,* arenaceous and argillaceous beds may be said to prevail, with interstratified limestones, calcareous grits, and marls. The *arenaceous* members are either pebbly conglomerates of a rusty yellow, or sands little indurated and variously tinted by the oxide and silicate of iron. The sands are seldom sufficiently consolidated to form sandstones; and the conglomerates are often mere layers of rolled pebbles, without any cementing matrix. The *argillaceous* beds also present many varieties; some being

almost pure laminated clay of a dull blue colour, others of a brownish tint, with a slight admixture of sand, while many pass into marls more or less calcareous. None of these clays are so compact as to form shales; indeed lamination is more frequently absent than otherwise, there being nothing except their fossils and associated beds to distinguish them from the clays of subsequent alluvial valleys. The *calcareous* layers are still more varied in their composition and aspect, and bear no resemblance to the indurated half-crystalline limestones of older formations. The marine limestone of the Paris basin is of a coarse sandy texture; that of Austria a rough coralline rock: the fresh-water beds near Weimar are hard and compact; those of other districts are soft, marly, and full of shells. In some localities marls are so calcareous as to be used as limestones, while in others they pass into soft friable clays. From this extreme diversity of composition, it is evident that many agencies have been concerned in the deposition of the tertiary system, and that most of them have been of a local character, producing results not differing widely from those of the present day.

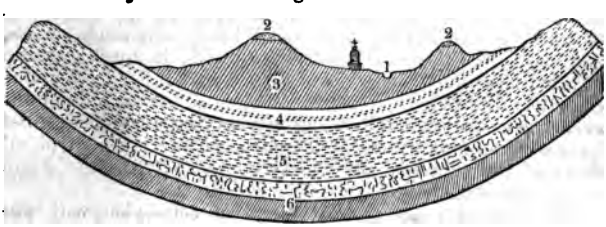
241. *The succession of strata* is no less varied than their mineral composition. As at the present day distant rivers are depositing different sorts of material at one and the same time, so in distant tertiary basins different strata variously succeed each other. Luckily, none of the deposits are of great thickness, and as they have been closely examined for the sake of their fossils, the alternations of the beds have been pretty accurately ascertained. The following is a descending section of the Paris basin, according to Cuvier and Brogniart:—



annexed section shows the order of their occurrence to the south of London :—

4. BAGSHOT SANDS.
3. LONDON CLAY—of a dull gray, or blue, or ochraceous colour ; often full of green grains. Septaria and other ferruginous nodules occur in some parts. Numerous fossils.
2. PLASTIC CLAY AND SANDS—sands of various colours, with occasional beds of lignite ; also layers of sandy clay, with or without shells.
1. SANDS—green and ferruginous, accompanied by flint pebbles, oyster shells, &c.

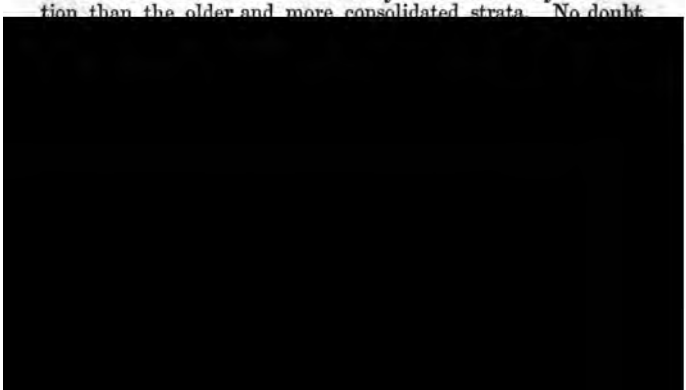
In other parts of England the order of occurrence is somewhat different. It may be stated, however, in general terms, that the sands are most extensively developed ; the clays chiefly in the southern basins ; while at Oxford, Ramsholt, &c. the upper beds consist of a coarse conglomerate of corals, sand, pebbles, shells, &c. locally known as the "Crag," and so calcareous in some places as to be used as a limestone. As with the Paris and English deposits, so with other tertiary basins in Europe ; those of southern France, Spain, Italy, Austria, Hungary, &c. —all showing an irregular succession of clays, sands, marls, lignites, and gypsum, which, when examined in relation to their positions, modes of aggregation, and fossils, are clearly referrible to the same period of formation. The following engraving illustrates the tertiary deposits of the Thames basin, with the subjacent chalk and green-sand :—



1. River Thames ; 2. Marine sands ; 3. London clay ; 4. Plastic clay and sands ; 5. Chalk with flints ; 6. Green-sand and Gault-clay.

242. *As to the extent of country occupied by tertiary deposits,* there is yet no very accurate knowledge, inasmuch as many sands and clays, now regarded as the alluvium of existing valleys, may hereafter be referred to this system ; and several areas of gravel, now looked upon as tertiary, be classed with more recent accumulations. As developed in Europe, the system spreads over wide areas, all remarkable for their conformation and connexion with the outline of existing seas.

Indeed, were the islands and continent of Europe to be submerged to the depth of 600 or 800 feet, the waters of the German, Baltic, English Channel, and Mediterranean seas, would cover most of the tertiary strata, showing that, with the exception of the general elevation which raised them into dry land, there has been comparatively little subterranean disturbance since the time they were deposited. In Britain the formation is exhibited in Hampshire, Isle of Wight, in the basin of London, and from the Thames northwards along the coast to the mouth of the Yare; but has not been detected either in Ireland or Scotland, though several gravel and clay deposits in the latter country may yet be discovered to belong to the same era. It occurs interestingly developed near Paris; trends along the north coast of France, Belgium, Westphalia, Holstein, and Jutland, in apparent connexion with the German Ocean; spreads over the level tract lying between the Baltic and Northern Ocean in Russia; and occupies the greater portion of the central flats which lie between the Baltic and Black seas. Besides these expanses, there are many secluded patches along the valleys of the Rhone and Danube, the Swiss lakes, and the Italian shores of the Mediterranean. The system has also been detected along the southern basis of the Himmalehs, and in several of the North American valleys; and when geological research has been farther extended, there is little doubt of its being discovered in other quarters of the world. In speaking of the extent of country occupied by deposits of incoherent sands, marls, and clays, like those of the tertiary epoch, it must be borne in mind how much more waste they would suffer by denudation than the older and more consolidated strata. No doubt



strata. Along the Rhine, in Hungary, and in central France, the igneous elevations assume a more diminutive aspect—those of Auvergne never arranging themselves in a continuous axis, but presenting a congeries of conical crateriform hills of no great altitude. In their composition, these igneous rocks are chiefly trachytic—passing from a pretty compact grayish felspathic mass to scoriaceous tufa; but in no case presenting the dark bituminous aspect of the coal-measure traps, nor the amygdaloidal and porphyritic texture of those associated with the old red sandstone.

244. *Respecting the geographical aspect* of tertiary districts, the general absence of igneous rocks would indicate a level and somewhat unvaried scenery; and this is the feature which prevails in the wide tertiary plains of northern and middle Europe. In England the strata partake of the undulations of the subjacent chalk, principally developed, however, in the flatish basins of London and Hampshire. From the open and porous character of the sands and gravels, tertiary soils are in general light and dry, capable of profitable cultivation, but by no means naturally fertile. The hills and vine-growing slopes of Auvergne* can scarcely be considered as reposing on a tertiary basis any more than the snow-clad crags and peaks of the Alpine range, both of which form decided exceptions to the general rule.

245. *The organic remains of the system* constitute its most important and interesting feature. The fossils of earlier periods presented little analogy, often no resemblance, to existing plants and animals; here, however, the similitude is frequently so complete, that the naturalist can scarcely point out a distinction between them and living races. Geology thus unfolds a beautiful gradation of being from the corals, molluscs, and simple crustacea of the grauwacke—the enamelled fishes, crinoidea, and cryptogamic plants of the lower secondary—the chambered shells, sauroid reptiles, and marsupial mammalia of the upper secondary—up to the true dicotyledonous trees, birds, and gigantic quadrupeds of the tertiary epoch. The student must not, however, suppose that the fossils of this era bring him up to the present point of organic nature, for thousands of species which then lived and flourished became in their turn extinct, and were succeeded by others long before man was placed on the earth as the head of animated existence. Of *Plants*, few marine species have been detected; but the fresh-water beds have yielded cycadeæ, coniferæ, palms, willows, elms, and other species, exhibiting the true dicotyledonous structure. Nuts allied to those of the cocoa and other palms have been discovered in the London

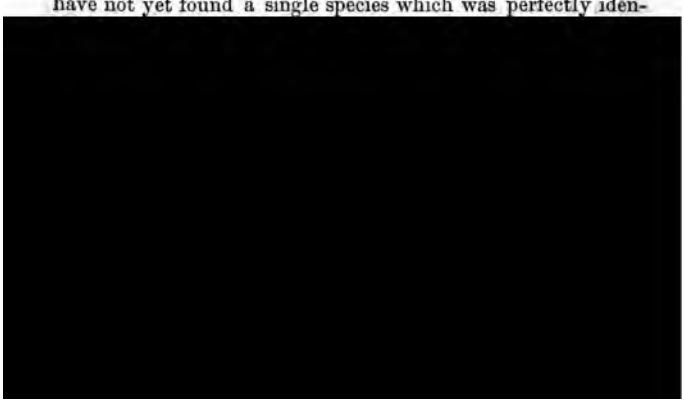
* Scrope's work on Auvergne (Geology of Central France?) of deep interest to general readers. Dr Mantell

clay; and seeds of the fresh-water *characeæ*, or stoneworts, known by the name of *gyrgonites* (Gr., *gyros*, curved, and *gonos*, seed), are common in the same deposit. Of the *Radiata*, *Articulata*, and *Mollusca*, so many belong to existing genera, that the circumstance has suggested a classification of tertiary rocks according to the number of recent species which they contain. Thus, if out of 100 fossil shells 80 should belong to recent species, the deposit in which they are imbedded is presumed to be of later origin than one from which only 10 per cent. of recent shells can be obtained. Proceeding upon this plan, M. Deshayes and Mr Lyell arrange the entire system into the following groups, as further explained in note, page 72 :—

PLEISTOCENE—Sicilian deposits, with 95 per cent. of recent species.
PLEIOCENE—Italian and Crag deposits, with 41 per cent. of recent species.
MEIOCENE—Vienna, Bordeaux, Turin, &c. 18 per cent. of recent species.
EOCENE—Paris, London, Belgium, 3½ per cent. of recent species.

From the above per centage the student will perceive, with respect to the marine mollusca of the tertiary era, that they approach existing forms too nearly to require any particular description.

246. *The vertebrate animals* make a similar approach to, or recession from, existing races as we ascend or descend among the tertiary strata. "The *Fishes*," says M. Agassiz, "are so nearly related to existing forms, that it is often difficult, considering the enormous number (above 8000) of living species, and the imperfect state of preservation of the fossils, to determine exactly their specific relations. In general, I may say that I have not yet found a single species which was perfectly iden-



in the Paris basin, referrible to the genera—buzzard, owl, quail, woodcock, sea-lark, curlew, and pelican.

247. *The mammalia of the tertiary strata* are those fossils which have most attracted the attention of palæontologists; and this deservedly so, from their being the prototypes of many existing species, and as marking the dawn of conditions suited to the Fauna of the present day. Of these ancient forms, between fifty and sixty species have been determined, a majority of which belong to a division of the order *Pachydermata*, now only represented by four living species; namely, three tapirs, and the daman of the Cape. This division comprehends most of the *theroid* animals, now so frequently alluded to in works on geology, of which the *palæotherium* (see fig.) was one of the most prevalent and characteristic. A detailed enumeration of the mammalia of this era would be inconsistent with the rudimentary nature of this treatise; we shall therefore merely advert to the leading orders now determined by the most eminent fossil anatomists. *Quadrumana* (four-handed, or monkey tribe), one or two species from the eocene beds of the English basins; *Marsupialia* (pouch-nursing), three or four species of a diminutive size; *Cheiroptera* (hand-winged), two or three species of bat, chiefly from the gypsum beds of Montmartre; *Insectivora* (insect-eaters), partial remains of a species of mole; *Carnivora* (flesh-devourers), several species have been determined allied to the bear, hyæna, fox, dog, seal, cat, weasel, &c.; *Rodentia* (gnawers), ten or twelve species allied to the beaver, rat, hare,

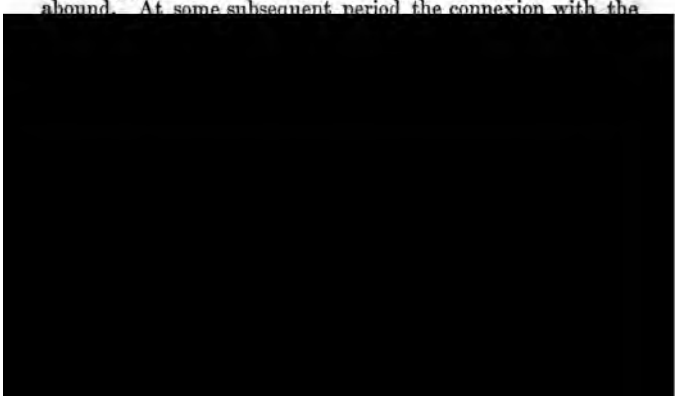
Form of Palæotherium.

Restored Form of Deinotherium.

lagomys, squirrel, &c.; *Pachydermata* (thick-skinned), many genera and species, such as the mastodon, the deinotherium

(see fig.), elephant, hippopotamus, rhinoceros, horse, boar, tapir, and a host of animals allied to the tapir; *Ruminantia* (cud-chewers), a few species, as the stag, deer, elk, antelope, ox (?), &c.; *Cetacea* (whales), one or two species; and gigantic *Edentata* (toothless animals), now faintly represented by the sloth, the ant-eater, and the diminutive armadillo.

248. *Of the conditions of the world during the deposition of the tertiary strata*, we are enabled to form some estimate from the nature of their fossils, and from the peculiar composition and aggregation of their rocky materials. So far as Europe is concerned, part of the existing land must have been then elevated above the waters, forming a series of insular ranges, with flat valleys and shallow seas between. From these islands, and from continents now submerged, rivers of considerable extent seem to have borne sand, clay, and vegetable debris, and to have deposited them in the seas and estuaries, while gravel, flint pebbles, broken corals, and shells, were strewn along the shore by ordinary littoral influences. Such materials would give rise to beds of sand, clay, gravel, lignite, and calcareous conglomerate, enclosing marine remains, with others of fresh-water and terrestrial origin brought down by the rivers. But several tertiary basins exhibit strata of decided fresh-water origin, alternating with others as decidedly marine; and to account for this phenomenon, we must have recourse to another set of agents. In the deltas of many modern rivers, like that of the Niger, lagoons of fresh-water are frequently cut off from connexion either with the branches of the river or with the ocean, and in these myriads of shell-fish, aquatic plants, crocodiles, hippopotami, and other fresh-water and amphibious races abound. At some subsequent period the connexion with the



the cycadeæ, palms, cocoa nuts, and monkeys of the English tertiaries, and the mastodons, elephants, rhinoceroses, hippopotami, crocodiles, and turtles of the Paris basin, must have enjoyed a temperature similar to that of the present tropics. The beds of lignite bear evidence of a luxuriant vegetation for the support of so many huge graminivora; while the presence of birds, insects, and the higher orders of mammalia, point to atmospheric and other vital conditions little different from those now existing. In fact, we find in the deltas of the Ganges and Niger—in their jungles, lagoons, and swamps—in their elephants, hippopotami, and crocodiles—almost perfect analogies to those estuaries and shallow seas in which the tertiary strata of Europe were deposited.

249. *In an economical point of view*, the tertiary strata are of considerable local importance. The celebrated *burr* millstones of France are obtained from the upper fresh-water siliceous limestones of the Paris basin; some of the strata of which also furnish marble capable of receiving a high polish. Marked by the numerous shells which are imbedded in it, this marble is by no means unornamental, and has been used in the construction of the *jets d'eau* in the galleries of the Tuilleries. Many of the fresh-water limestones rapidly disintegrate on exposure to air and moisture, and, falling down to the state of marl, are used as manure; while the "crag" is occasionally so calcareous, as to serve the ordinary purposes of limestone. Pipe and potters' clay are extensively obtained both from the London and Paris basins; the term *plastic*, applied to the lower beds, being derived from the circumstance of the clay readily receiving the mould or form of the potter (Gr., *plasso*, I form). Gypsum (sulphate of lime) is perhaps the most valuable member of the deposit; it is found abundantly in the Paris basin, and when calcined, reduced to powder, and kneaded with water, forms the well known *plaster of Paris* so extensively used by image-makers, plasterers, stereotype-founders, and others. Gypsum has also been recently applied as a top-dressing to crops, and as a fixer of the volatile principles of organic manures. Lignite (Lat., *lignum*, wood), or wood-coal, is found in some tertiary districts, the only deposit of importance in England being that of Bovey Hayfield, near Exeter. Amber frequently occurs with these lignitic beds, and appears to have been a gum or gum-resin exuded by the trees with which it is associated.

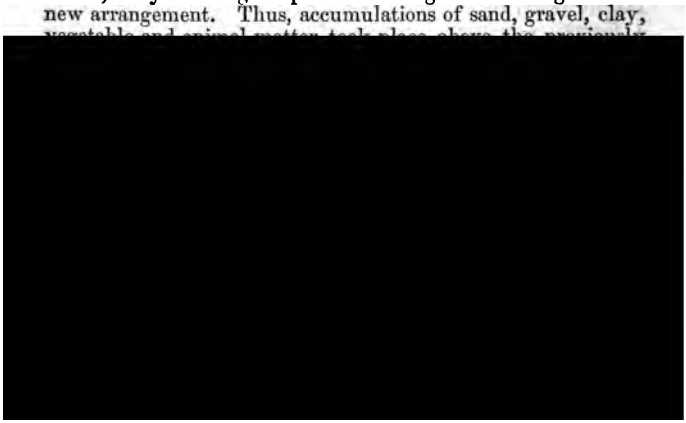
EXPLANATORY NOTE.

THEROID ANIMALS.—The termination *therium* (Gr. *therion*, a wild beast) is adopted in geology to designate certain classes of fossil

mammalia whose structure and habits have not yet been fully established by anatomists. The individual animals are characterised by a prefix which applies to some peculiarity of form, the place where found, or the name of the discoverer. Thus we have the *deino*therium (terrible wild beast); the *palæo*therium (ancient); the *anoplo*therium (unarmed, having no weapons of defence); the *mega*therium (great); the *elasmo*therium (from the laminated structure of its teeth); the *anthraco*therium (found in the lignitic beds); the *caino*therium (recent); the *siva*therium (found in the Sivalic range of the Himmalehs); &c. Though most of these animals are found in tertiary deposits, it would appear that some, such as the megatherium, outlived that era, and continued inhabitants of the globe long after the commencement of the current epoch.

SUPERFICIAL ACCUMULATIONS.

250. *After the deposition of the Tertiary Strata*, a great change took place in the relative distribution of land and ocean. Most parts of Europe, America, and the other continents were elevated above the waters; other regions seem to have been submerged, and an arrangement of physical conditions established not differing widely from those now existing. But these new conditions did not for an instant arrest the degrading and transporting power of water, the wasting effects of the atmosphere, the disturbing efforts of volcanoes, or the progressive development of organic life: the same agents which had exerted themselves, from the beginning of time, in modifying the physical features of the world, continued their career, only differing in power and degree according to this new arrangement. Thus, accumulations of sand, gravel, clay,



1. Deposits now in progress, and depending upon ordinary causes.
2. Those whose origin depended upon ordinary causes now dormant.
3. Those which owe their origin to extraordinary causes now dormant.

A classification of this kind, however, is attended with so many difficulties, that it is next to impossible to adopt it with any degree of accuracy. For instance, it is often very difficult to distinguish the gravel of some ancient lake, containing bones of the stag, elk, and elephant, from true tertiary strata; and who shall decide whether certain inland ranges of sand and gravel arose from extraordinary or ordinary causes? Again, in many valleys alluvial matter has been accumulating from the time that they received their existing configuration up to the present day, thus making the most ancient and most recent of such deposits depend upon one long-continued and progressive agency. Further, an iceberg laden with rock debris and boulders, strewing its burden, as it melts away, along the bed of the ocean, is an ordinary operation; yet were the bottom of the sea, with its mud, gravel, and immense boulders, to be elevated into dry land, appearances would present themselves which geologists would be very apt to ascribe to violent and unusual operations of water. Under these circumstances, the more philosophical mode of treating the Superficial Accumulations will be to adopt no classification which involves either the time, the ordinary or extraordinay cause of their formation; but simply to treat them in succession according to their composition, or the agents obviously employed in their deposition. Following out this view, the principal agencies and their results may be arranged as under:—

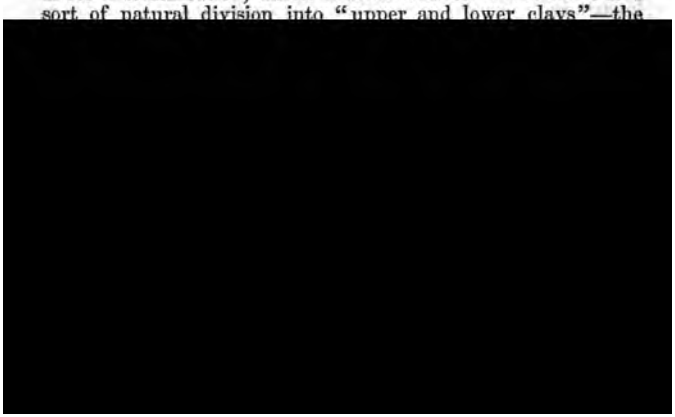
Agencies.	*Nature of Accumulations.*
DETRITAL.	Erratic blocks or boulders; dark tenacious clays.
	Ossiferous gravels, sands, and pebbly clays.
	Ossiferous caves, fissures, and breccia.
MARINE.	Raised or ancient beaches; submarine forests.
	Marine silt, sand-drift, shingle beaches, &c.
	Submarine deposits and accumulations.
FLUVIATILE.	Terraces on valley sides, marking successive water-levels.
	Valley deposits, consisting of river sand, gravel, silt, &c.
	Deltoid or estuary deposits, ancient and progressive.
LACUSTRINE.	Sites of ancient lakes now silted up with various debris.
	Marls, such as shell, clay, and calcareous marls.
	Lacustrine silt, and accumulations now in progress.
MINERAL AND CHEMICAL.	Calcareous—calc-tuff, sinter, travertine, stalactites, and stalagmites.
	Siliceous and aluminous deposits from springs, &c.
	Saline and sulphurous deposits from springs, from the sea, volcanoes, &c.
	Bituminous exudations, pitch lakes, &c.

ORGANIC.	Vegetable—peat-mosses, jungles, vegetable drift. Animal—shell-beds, coral-reefs, &c. Soils—primitive earths, with admixtures of organized matter.
VOLCANIC.	Earthquakes—elevations and depressions, &c. caused by Volcanoes—elevations, disruptions, and other changes caused by Discharges and accumulations of lava, scoriæ, dust, &c.

The above synopsis comprises all masses of matter which produce any sensible modification of the earth's surface; other accumulations than these must be of a very local and limited description.

ERRATIC BLOCK, OR BOULDER, GROUP.

252. *The terms "erratic block group," "boulder formation," "diluvium," and "diluvial drift,"* are indiscriminately given by geologists to a thick mass of dark tenacious clay which overlies extensive districts, intermingled with numerous boulders having a rounded and water-worn appearance. There is nothing like regularity of deposit in this formation, unless it may be said that it attains the greatest thickness and uniformity of composition on extensive plateaus like those of the coal measures, at the eastern extremity of certain valleys, and on the south-eastern flank of hills belonging to the secondary period. The clay is generally of a dark blue colour, though in some localities it assumes a reddish hue. There are no lines of lamination in the mass, and no appearances of stratification, unless in some districts where there is a sort of natural division into "upper and lower clays"—the

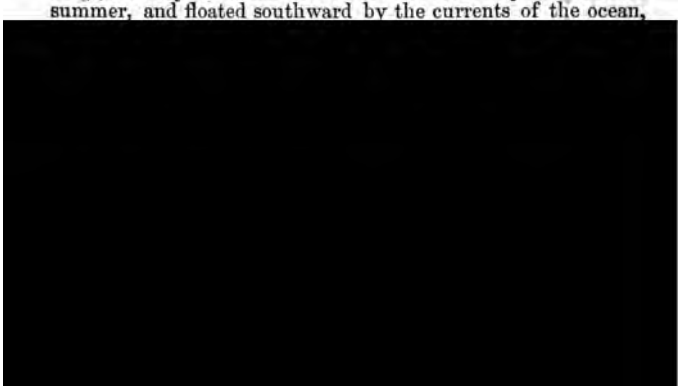


253. *Besides these patches which are interwoven with the clay*, there are independent accumulations of gravel, and rubbly masses of rock-fragments, which seem to have been formed contemporaneously with the boulder-clay, and by the same agency. In Britain such accumulations generally occupy the eastern extremity of longitudinal valleys, where they form curious ranges of flat-topped hillocks; abut against the base of some mountain; or gather, without regard to any order of arrangement, along the eastern flank of those trap hills which present a bold front or "crag" to the westward. They are found for the most part in more open situations than the clay, as if they had been arrested in their progress eastward by prominences and shallows, while the clays were borne to deeper and more sheltered recesses. Like the dark clays, they are destitute of organic remains, their larger pebbles are derived from primitive rocks, interspersed with fragments of sandstone, shale, and coal from the secondary formations.

254. *To account for the origin of the group thus described*, many theories have from time to time been advanced, of which only two deserve notice, as being at all adequate to the purpose intended. The *first* is that which supposes a set of powerful currents to have passed over Britain and the adjoining continent; these currents taking a course from the north and north-west towards the south and south-east, and sweeping before them clay, sand, gravel, and loose blocks, which were deposited, as the force of the waters abated, without any order or arrangement. How long the currents continued, theorists do not aver; but from the water-worn aspect of the boulders and gravel, an indefinite period is allowed. With respect to the direction of the drifting force, little doubt is entertained, for many reasons:—1. Blocks of granite, gneiss, &c. which must have been derived from the Grampians, are found scattered along the eastern lowlands of Scotland; primitive rocks from the Lammermuir and Cheviot ranges are detected in the vale of the Tweed and in Northumberland; others from the Cumberland mountains are widely dispersed over Durham and the east of Yorkshire; boulders from the Welsh range are found in the midland counties of England; while the erratic blocks of Friesland and Germany point to the Scandinavian ridge as the source from which they were derived. 2. Those hills which range east and west have, without exception, their western brows swept bare, while their eastern flanks are thickly strewed with gravel and boulders. 3. Many accumulations of gravel bear evidence of their having been piled up by a force from the north-west. 4. Blocks evidently derived from the outcrops of certain strata are often

found among the debris a few yards to the south-east, showing clearly that the transporting power passed over them from the north-west. 5. The supposed currents have been modified in their direction by ranges of hills, so as to set the volume of water with greater rapidity down the valleys which lie between them, as the greatest accumulations of drift and boulders are found at the eastern extremities of such gorges and valleys. But while no doubt is entertained either as to the agency of water in the formation of these accumulations, or as to the direction in which the waters flowed, great difficulty is felt in conceiving any current sufficiently powerful to sweep before it blocks of several tons weight, and that over heights and hollows for many hundreds of miles. Indeed it seems impossible to reconcile the theory of violent currents with the phenomena presented; for, granting the occurrence of some extraordinary cataclysm, during which the waters of the ocean were thrown over the land, the currents must have abated in velocity as they drew to a close, leaving the detritus to arrange itself more in accordance with the laws of gravity than what is exhibited in a mass of clay and boulders.

255. *The second theory* supposes that those portions of Europe now covered with erratic blocks were submerged after the deposition of the stratified formations; that this submergence was caused by some extraordinary revolution in the planetary relations of our earth; that it was accompanied by a change of climate, and other terrestrial conditions; that while in this state, icebergs and avalanches formed around the earlier mountains which were still left above water; and that these icebergs, as they were loosened from the shore by the heat of summer, and floated southward by the currents of the ocean,



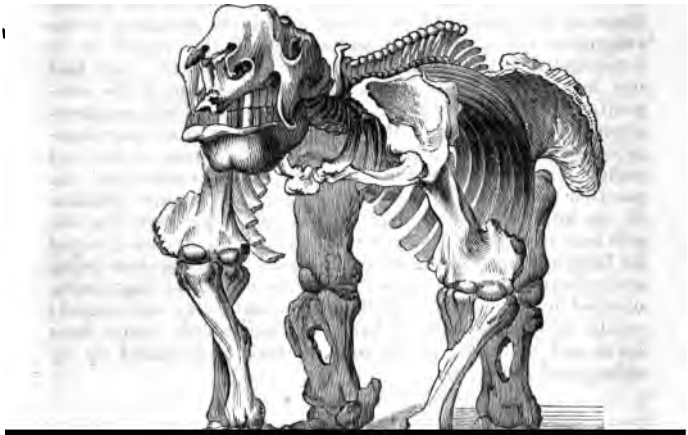
to this theory, it is easy to account for the south-eastward direction of the drift, for the Polar Ocean still maintains its great southward current to the equatorial seas, modified, undoubtedly, in its course, by the inequalities of the bottom over which it passes. The chief difficulty to be obviated is the temporary diminution of temperature which the north of Europe must have then experienced; and this can only be accounted for by some derangement in the planetary relations of our globe.

256. *Both theories are beset with many difficulties*, and though the latter accounts more satisfactorily for most of the phenomena of the erratic block group, still there are many points respecting the distribution and extent of the deposit to be investigated before either can be finally adopted. All that can be affirmed in the present state of the science is the composition and nature of the clay, gravel, and boulders, as above-described—the course of the currents concerned in their deposition—the fact of the land having a configuration of hill and valley not differing much from what now exists—and the peculiar scantiness, if not total absence, of organic remains. If the latter theory be adopted, it is easy to perceive how the soft bottom of the ocean, as it was elevated into dry land, would be furrowed and channeled by the receding waters—here being swept bare of its mud, but retaining the boulders; there being covered by accumulations of transportable clay and gravel; while the deeper hollows being left undrained, would form lakes and morasses, which were in turn to be silted up by subsequent material.

OSSIFEROUS SANDS AND GRAVEL.

257. *Next in point of antiquity to, if not contemporaneous with, the clays and boulders of the preceding group*, may be ranked those ossiferous sands and gravels found scattered at intervals over the valleys of Britain, the continent of Europe, and the river plains of North America. They are termed *ossiferous* (Lat. *os*, a bone, and *fero*, I bear), from their containing bones of elephants, hippopotami, horses, bears, deer, and other animals, which belong to existing species, but do not now inhabit the regions where these remains occur. For instance, large portions of England, Wales, Scotland, and Ireland are covered by irregular accumulations of rounded pebbles and gravelly sands, in which are found bones of the elephant, hippopotamus, &c. none of which have been known in this country within the historic period. In similar deposits the skeletons of elephants and mammoths have been discovered in

Siberia and the north of Europe; the bones of the mammoth, mastodon, and megatherium in America; and even among the Esquimaux of the Polar seas Captain Ross and Mr Simpson observed platters fashioned from the fossil grinders of these gigantic mammalia. Neither at present, nor throughout the whole historic period of four thousand years, have any of those countries been in conditions of climate to support such huge graminivora, and therefore geologists are compelled to assign a very remote and ancient origin to the gravels in which their relics are entombed.



character of the pebbles enables the geologist often to decide with certainty as to the quarter from whence they were drifted; and in Britain this generally corresponds with that from which the erratic blocks were derived. Like the boulders, the great mass of the pebbles are from primitive rocks, interspersed with secondary sands, rolled flints, and calcareous cement. The imbedded bones are more or less impregnated with iron and lime, are harder and heavier than recent bone, but never so much petrified as to obliterate the bony structure. The gravels have all a light ferruginous tint, and can only be distinguished in certain localities from true tertiary gravel by the recentness of their fossils, or by some circumstance of position or mode of aggregation.

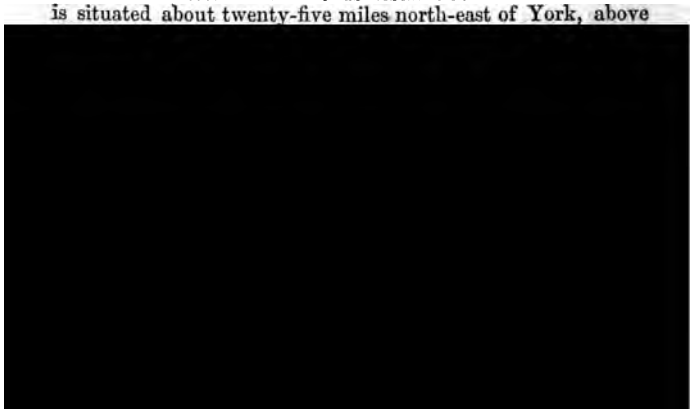
259. *Much uncertainty prevails with respect to the origin and aggregation* of these ossiferous sands and gravels. Many of them are no doubt local, and have been formed by the action of rivers, the silting up of lakes and other extensive shallows; and could such be separated from those which appear to have been accumulated by some very powerful and extensive agency, the task were greatly simplified. Unluckily, however, this seems to remain an insuperable difficulty, so that geologists are compelled to class together all deposits of ancient ossiferous gravel into one group, without much regard to the agencies concerned in their accumulation. This grouping is rendered still more indefinite by the assertion of some eminent geologists, that ossiferous gravels have been found underneath the erratic boulder clay, containing the same kind of bones with those above it. Should this be the case, it would tend to establish the theory, that the ossiferous gravels and erratic blocks took their origin from the same set of unusual causes; that they belonged to an era which was posterior to the tertiary, and prior to the existing arrangements of nature; and that before this epoch, which was of considerable duration, many of the tertiary races had died away, and been succeeded by others, most of which still exist, though now extinct in the regions where they then flourished.

OSSIFEROUS CAVES, FISSURES, AND BRECCIA.

260. *Belonging to the same era with the ossiferous gravels*, and only here separated for the sake of perspicuity, occur numerous caverns and fissures filled with the bones of elephants, rhinoceroses, hyænas, bears, deers, and other animals. These caverns are found in England, France, Belgium, Germany, along the coasts of the Mediterranean, in North America, and in Australia. They are situated almost exclusively in

thick strata of limestone, a rock peculiarly liable to be fissured and worn out by the action of springs and subterranean waters. Among the mud of these ancient caverns, or covered over with calcareous incrustations, lie the bones of land quadrupeds perfectly preserved, and capable of being compared with existing races. "The result," says Professor Phillips, "is extremely remarkable: instead of a large proportion of the existing species of animals, which, during the early periods of history, if not in later times, might have been expected to fall into fissures, retire into caves, or be dragged by wolves to their dens, we find the greater number of bones to belong to elephants, large feline animals, the rhinoceros, hippopotamus, elk, hyæna, indiscriminately entombed with oxen, deer, and many smaller animals." Masses of bones are also found filling fissures and other openings in rocks, mingled with pebbles, mud, fragments of shells, &c. To such accumulations the term *osseous breccia* is applied, from the fragmentary nature of the compound.

261. *The number of ossiferous caverns* is very great, but we can only allude to those which occur in England. In general they are situated on the limestone escarpments of the secondary hills, or on the terraced side of some valley. In the latter case, they are considerably above the existing bed of the valley, though at one time they must have been on a level with the waters which occupied its expanse. The most celebrated are Banwell Cave and Hutton Hole in the Mendip hills, Dream Cavern near Wirksworth, Peak Cavern in Nidderdale, Kents Hole at Torquay, and Kirkdale Cave in Yorkshire. The latter has been thus described:—"Kirkdale Cave is situated about twenty-five miles north-east of York, above



irregularly into bosses, lay beneath the feet. This being broken through, yellowish mud was found about a foot in thickness, fine and loamy toward the opening, coarser and more sandy in the interior. In this loam chiefly, at all depths, from the surface down to the rock, in the midst of the stalagmitic upper crust, and, as Dr Buckland expresses it, 'sticking through it like the legs of pigeons through a pie-crust,' lay multitudes of bones of the following animals :—

CARNIVORA—hyæna, tiger, bear, wolf, fox, weasel.
PACHYDERMATA—elephant, rhinoceros, hippopotamus, horse.
RUMINANTIA—ox, three species of stag.
RODENTIA—hare, rabbit, water-rat, mouse.
BIRDS—raven, pigeon, lark, duck, snipe.

The hyæna's bones and teeth were very numerous—probably two or three hundred individuals had left their bodies in this cave; remains of the ox were very abundant; the elephants' teeth were mostly of very young animals; teeth of hippopotamus and rhinoceros were scarce; those of water-rats very abundant. The bones were almost all broken by simple fracture, but in such a manner as to indicate the action of hyænas' teeth, and to resemble the appearance of recent bones broken and gnawed by the living Cape hyæna. They were distributed 'as in a dog-kennel,' having clearly been much disturbed, so that elephants, oxen, deer, water-rats, &c. were indiscriminately mixed; and large bones were found in the narrowest parts of the cavern. The peculiar excrement (album græcum) of hyænas was not rare; the teeth of hyænas were found in the jaws of every age, from the milk tooth of the young animal to the old grinders worn to the stump: some of the bones were polished in a peculiar manner, as if by the trampling of animals."

262. *The conclusions to be drawn respecting these ossiferous caverns* are—1. that some of them formed the dens of ravenous animals, like the wolf and hyæna, which dragged in the carcases of other animals, and feasted upon them in quiet, leaving the bones to be covered in process of time by incrustations of calcareous matter; 2. that others were partially filled by these means, and partly by the drifting in of bones and dead animals by some extraordinary inundation; 3. that many (fissures especially) were filled by the same drifting process, or by the accidental falling in of the animals; 4. that several appear to have been used during successive ages as retreats for animals of all kinds, and even for man himself, as remains of savage life are found in caverns, the floors of which are formed of calcareous incrustations, mud, and the bones of animals extinct long before man made his appearance.

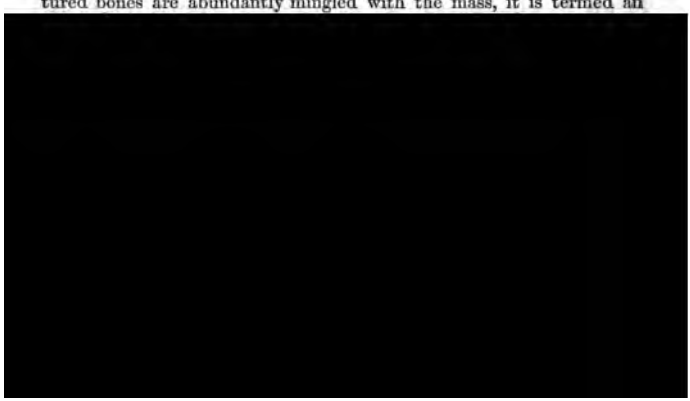
EXPLANATORY NOTE.

BOULDERS, OR BOWLDERS — a term generally applied to rounded masses of stone lying on the surface, or loosely imbedded in the subsoil. Boulders are found of all sizes, those of granite, syenite, and primitive greenstone being the largest, and often weighing from ten to thirty tons.

DILUVIUM.—The terms diluvium, alluvium, and colluvium, are to be found in all geological works, but the distinctions made between them are often not very obvious. *Colluvium* (Lat., *con*, together, and *luo*, I wash) is meant to apply to masses of detrital matter washed together, without hinting at the nature of the force by which they were accumulated. *Alluvium* (Lat., *ad*, to) is generally applied to matter brought together by the ordinary operations of water, such as river silt; while *diluvium* (Lat. *dis*, asunder), on the other hand, is regarded as implying the extraordinary action of water. In this sense diluvium was at one time restricted to those accumulations of gravel, &c. supposed to have been the consequence of the Deluge; but it has now a wider signification in geology, being applied to all masses apparently the result of powerful aqueous agency.

MORAINES — the name given in Switzerland to the longitudinal deposits of stony detritus which are found at the bases and along the edges of all the great glaciers. The formation of these accumulations is thus explained by Professor Agassiz:—The glaciers, it is well known, are continually moving downwards, in consequence, probably, of the introduction of water into their fissures, which, in freezing, expands the mass; and the ice being thus loosened or detached from the rocks below, is gradually pressed forward by its own weight. In consequence of this motion, the gravel and fragments of rocks which fall upon the glaciers from the sides of the adjacent mountains are accumulated in longitudinal ridges, or *moraines*.

OSSEOUS BRECCIA.—Any rock composed of an agglutination of angular fragments is designated by the Italian word *breccia*; and when fractured bones are abundantly mingled with the mass, it is termed an



possible to mistake for any other appearance. Where an elevation of the land takes place, this beach will form a terrace composed of sand, gravel, and other marine debris, ranging more or less parallel with the new line of coast: such terraces are known by the name of *raised or ancient beaches*. But the earth's crust is as liable to depression as elevation; and though depressions are not so obvious, in consequence of the overflow of the ocean, still, in certain localities, the ebbing tide exposes the stumps of trees and other terrestrial evidences of these districts having at one time formed dry land. Phenomena of this kind are known as *submarine forests*, and are classed with ancient beaches, as showing the depressing and elevating forces to which the terrestrial crust is still subjected.

264. *Raised beaches* have been discovered in many parts of the world; in some, evinced by a single terrace, in others, by a succession of terraces. Several of these beaches are comparatively recent—as the Chili upheave of 1822, and the Ullah Bund at the mouth of the Indus in 1819 (par. 74)—and are obviously the results of local earthquakes and volcanic eruptions. Others are of more ancient date, though still coming within the historic period; while most of the higher terraces evidently belong to the dawn of the present geological era. Examples of such phenomena occur in the valleys of the Forth and Clyde, and along many parts of the coast of Scotland. One terrace, ranging from 40 to 60 feet above the present sea-level, is very continuous, and contains the shells of the limpit, whelk, cockle, common buccinum, and other existing species. It forms the plateau on which many of our modern sea-ports are situated, and preserves an outline generally parallel with the existing shore. Traces of a lower terrace, ranging from 6 to 15 feet above the present high-water mark, occur at several points on the eastern coast; but doubts are entertained whether it might not be the result of other causes than terrestrial elevation. As in Scotland, so in England evidences of a former sea-beach have been detected along the coasts of Lancashire, Yorkshire, and Durham, in the valley of the Mersey, and in the Bristol Channel. The same terraced appearances, with the remains of existing sea-shells, are found on the coasts of France, Portugal, Sicily, Greece, Norway, Sweden, and other parts of the European sea-board. In the Mediterranean, one terrace, nearly 50 feet above the sea, and full of shells, is discernible at many distant parts of the shore; on the coast of Norway, accumulations of marine shells are found nearly 200 feet above the existing beach; and along the borders of the Baltic, well-defined plateaus of marine detritus occur at elevations varying from 50 to 100 feet. All

these examples, with many others which might be adduced from the coasts of South and North America, point to successive elevations of the land, analogous to those by which the stratified formations were raised from their seas of deposit into open day. The remains found in the gravel and sand of these beaches are chiefly shells belonging to *species* now inhabiting the ocean, though a careful examination detects *varieties* apparently extinct. The more elevated terraces, like those of Scotland and Scandinavia, are evidently of great antiquity, and where they occupy wide expanses in ancient firths and bays, are apt to be mistaken by the superficial observer for true diluvial or even tertiary gravels.

265. *With regard to the origin of submarine forests*, geologists are somewhat at variance—one class of theorists advancing such phenomena as evidences of submergence, another contending that they merely occupy low flat districts, which have been successively lost and won by the sea. Without advocating either hypothesis, it may be stated that the sites of these so-called forests are generally flattish districts a few feet under the ordinary sea-level, and when exposed after a storm, or during ebb tides, present a series of half-fossilised stumps, with their roots imbedded in a stratum of dark-blue clay, evidently the soil in which they grew. The stumps have undergone various degrees of petrifaction, and many of them are also incrusted with iron pyrites. Phenomena of this kind have been detected in the estuary of the Tay, in the Firth of Forth, on the coast of Hampshire, and other places—proving, to all appearance, that the land in which they grew had been submerged beneath the ocean. Those who oppose this view, suppose the trees to have grown in low alluvial tracts, which were

were instrumental in modifying its surface during the deposition of the earlier formations. The results of existing forces may be insignificant when compared with those of former periods, but they are precisely analogous. An elevation of 100 feet may produce a very narrow terrace of gravel, where the land shelves rapidly beneath the water; but where the sea is shallow, as in most bays and estuaries, it will lay bare thousands of acres composed of mud, clay, sand, gravel, and marine exuviæ. A new formation would thus be constituted as peculiar and as characteristic of its era and origin as the tertiary or any other system of strata.

MARINE SILT, SAND-DRIFT, SHINGLE BEACHES, &c.

267. *Under the term "Marine Silt"* is comprehended all those masses of sand, mud, clay, gravel, &c. which are still in progress of accumulation along the existing shores of the ocean. Waves, tides, and other oceanic currents, are the forces by which they are collected and arranged, although a great, perhaps the greater, proportion of the material is derived from the land by the ceaseless transport of streams and rivers. It is necessary, however, to form geological distinctions between marine, estuary, river and lake deposits, as far as practicable, according to the agency more immediately concerned in their aggregation; for it is only by so doing that we are enabled to account for the peculiarity of their organic remains, and therefrom to form correct ideas respecting the character of the earlier formations. Along the entire shore of the ocean, drifted matter is always more or less accumulating; scantily around headlands and exposed places, where the sweep of the tidal current is powerful; abundantly in sheltered bays and recesses. Of the extent of such deposits it is impossible to form anything like a correct estimate, travellers and voyagers having hitherto directed little or no attention to the geological features of the countries which they visit. Instances of marine silt are afforded by the sands of Tentsmoor and Pilmoor between the Tay and St Andrews in Scotland, by the "warp" yearly reclaimed near the mouth of the Humber, the fens of Lincoln and adjoining counties, the extensive sands and marshes near Yarmouth, the Chesil bank at Portland, and the flats of Somerset and Gloucester on the estuary of the Severn. Some of these tracts are of considerable extent; but they are insignificant compared with what has taken place in other regions. The isthmus of Suez, for example, which is now 27 miles broad, is said to have doubled its width since the time of Herodotus (4000 years ago); Tehama, a country on the Red

Sea, has increased from three to six miles seaward since the Christian era; Tyre and Sidon, sea-ports mentioned in Scripture, are now several miles inland; hundreds of square miles of Holland, and the other Low Countries of the continent, are the direct formation of the existing seas.

268. *Sand-drift* is so intimately connected with marine silt, that both may, without much impropriety, be considered as one deposit. When the latter is chiefly composed of sand and comminuted shells, its surface, on being exposed by the ebbing tide, becomes so dry and light as to be easily borne about by the wind. Blown into slight eminences and irregular ridges, a portion of it is placed beyond the reach of the returning tide, and this process, repeated year after year, gives rise to extensive flats of sand curiously blown into *dunes* or little hillocks, and scooped out into hollows or *bunkers*. The seeds of the arundo arenaria (bent), elymus, and other maritime plants, soon spring up from this newly-acquired land, and bind it together by their long interweaving roots; other species succeed; and thus, in process of time, a vegetable sward gathers over it, and protects it from farther removal. Such accumulations are known by the name of *sand-drift*, and are of all ages, from that covered by many inches of vegetable soil, and brought under the plough of the farmer, to the loose sand which was drifted up during the ebb of the latest tide. Considerable tracts of this sandy formation are to be found skirting the coasts of every country—at some places in long narrow fringes, at others in wide expanses of many thousands of acres. It is always at the head of bays, in creeks, and other recesses, sheltered by some headland from the sweep of the tidal current, that such deposits occur; indeed, by the erection

coast by the conjoint action of the waves and tides. They occur only along exposed districts, from which the sand and finer debris is swept onwards to the more sheltered recesses. The battering force of the waves during high storms is so powerful, that masses of shingle are often found from 4 to 12 feet above ordinary tide-mark—leaving appearances very perplexing to the geologist who is unacquainted with the force of waves, the weight which stones lose when immersed in water, and the curious wedge-like arrangement which takes place among the individual pebbles. In addition to the forward motion imparted to these beaches by the waves, they are also subjected to the lateral current of the tides; and thus some of them move onward along the coast with so perceptible a motion, that they have been designated *travelling* beaches. Where shingle is found at considerable altitudes, or in places now removed from the sea, it is apt to be confounded with diluvial matter; but an attentive examination of the manner in which it is piled up, and the remains which it contains, will prevent such a mistake.

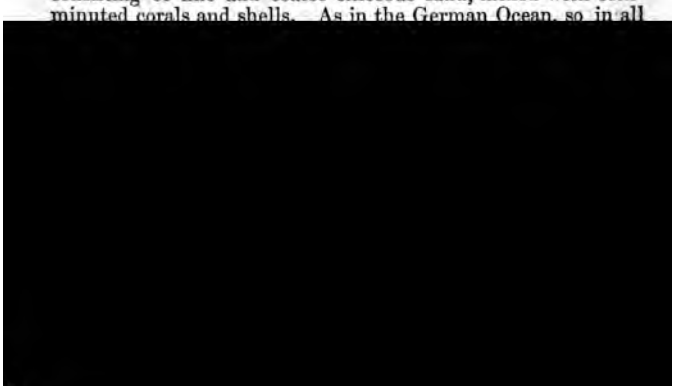
270. *The fossils imbedded in marine silt, sand-drift, and shingle,* all belong to existing races, though some of these races are now extinct in the countries where their remains are found. Marine silt, in many places, must be as ancient as the time when the land and sea received their present configuration; and from the peculiar nature of its formation, must contain both land and marine relics—the latter, however, greatly prevailing. Scarcely any of the fossils are petrified; most of them retain their usual structure; and unless where the sands are highly calcareous or ferruginous, there is no such thing as induration among the materials which compose these deposits.

SUBMARINE DEPOSITS AND ACCUMULATIONS.

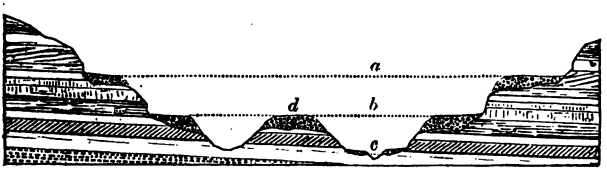
271. *Submarine deposits* are those which take place under the waters of the ocean, and are not subjected in any measure to littoral influences. Of such deposits geologists know scarcely anything with certainty, as few seas have been sounded with a view to detect the nature of the material accumulating beneath. This only we know, that where soundings have taken place, mud, sand, shells, broken corals, &c. have been found, evidently deposited there by submarine currents, which are modified in their velocity according to the inequalities of the bottom. Many of these currents are ascertained, and according to the regions whence they come, and over which they pass, so will the material

be which they are depositing along the bed of the ocean. Thus, the two polar currents, as they direct their course to the equator, carry with them icebergs and floes laden with the rocks and gravel of the arctic and antarctic islands; the gulf stream transports the sea-weeds, animal remains, and other debris of equatorial countries; while the outward current of the Mediterranean deposits in the Atlantic the products of its temperate regions. All these agents are unceasingly at work; and thus strata are now in formation along the bottom of the sea which, if elevated into dry land, would vie in extent with many of the secondary systems.

272. *Submarine accumulations have been detected* in the Yellow Sea, which is rapidly shoaling, in the Gulf of Mexico, in the Caribbean Sea, the German Sea, and in other divisions of the great ocean. The latter, according to Mr Stevenson, is deepest on the Norwegian side, where the soundings give 190 fathoms; but the mean depth of the whole basin may be stated at no more than 31 fathoms. The bed of this sea is traversed by several enormous banks, one of which, occupying a central position, trends from the Firth of Forth in a north-easterly direction to a distance of 110 miles; others run from Denmark and Jutland upwards of 105 miles to the north-west; while the greatest of all—the Dogger bank—extends for upwards of 354 miles from north to south. The superficies of these enormous shoals is equal to one-fifth of the whole area of the German Ocean, or about one-third of the extent of England and Scotland. The average height of the banks measures about 78 feet, the upper portion of them consisting of fine and coarse siliceous sand, mixed with comminuted corals and shells. As in the German Ocean, so in all



River-terraces are in general of no great breadth, but sweep along the sides of the valley, looking at a distance like a road embankment; hence the term "parallel roads" has been applied to those observed in Glen Roy. Their surfaces are covered to a considerable thickness with sand and pebbles—showing the long-continued action of water at that elevation. In some valleys there are two or three successive terraces (see fig.), marking the gradual declension of the rivers to their present level; and not unfrequently isolated mounds of gravel (*d*) stand out in the plain, of the same height with some of the terraces, as if these knolls had been shoals and sandbanks when the water occupied a higher level.



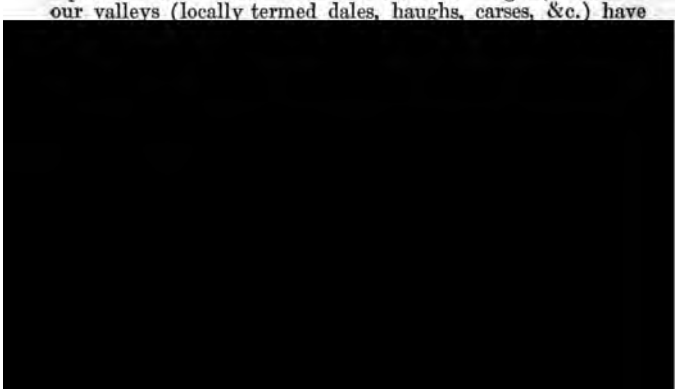
a, Upper terrace; *b*, Lower terrace; *c*, Existing river; *d*, Isolated mound of gravel, of the same height with the lower terrace.

274. *Such terraces are found indiscriminately in all parts of valleys*—at their heads, in their broad expanses, and in their estuaries. They are frequent where rivers descend from mountainous districts, but not very distinct and definite even should the water have formed glens and valleys of erosion many hundred feet in depth. The reason of this is, that the sides are so steep, so liable to landslips and other waste, that the terraces gradually become obliterated, leaving the bank as one continuous inclination. On the sides of valleys, properly so called, the case is otherwise, the terraces being left level and distinct as on the day they were deserted by the waters. These appearances would seem to indicate the existence of ancient lakes and other accumulations of water at a high level, which were either suddenly or gradually drained as the river cut through the barriers which produced them. Indeed, most of the valleys in our own island appear to have been at one time mere chains of lakes and morasses, now drained in consequence of the waters which flowed from them having gradually deepened their channels. This natural process of drainage is still going forward amid the swamps and lakes of other countries; and it is therefore easy to conceive how terraces, beaches, or ancient water-marks are formed, and will continue to be formed, until rivers have worn down their

channels to the lowest depth which the relative level of sea and land will permit. Instances occur in Glen Roy, in the valleys of the Tay, Eden, Tyne, Wear, Tees, Ouse, and other British rivers, all of which present the same level shore-like appearance. Similar terraces or *beaches* are found extending along large tracts in the vicinity of the great American lakes —showing that these "fresh-water seas," as they are not inappropriately termed, at one time occupied a higher level, and spread over much wider areas.

DEPOSITS IN VALLEYS.

275. *Deposits in valleys*, as distinguished from those in lakes and estuaries, are of a very complex description. In general, they consist of clay, marsh-silt, sand, gravel, and shingle—according to the nature of the country through which the river flows. Rapid streams leave along their banks only the heavier stones and gravel, and carry all light and impalpable matter to their embouchures. Sluggish rivers, on the other hand, deposit a great portion of their suspended impurities in the valleys through which they flow, thus forming inland tracts of alluvial soil. All rivers, however, are liable to sudden freshets, and as they wind and bend their way seaward, they tear up formerly-deposited matter—here piling up masses of shingle and boulders, there mounds of sand, and again overlaying the whole with a covering of mud. It is therefore impossible to say what was accumulated by the ordinary and what by the extraordinary operations of rivers, or to separate the ancient from the modern. Again, most of our valleys (locally termed dales, haughs, carses, &c.) have



great antiquity, and contain bones of the mammoth, elk, deer, horse, ox, bear, wild boar, wolf, and other animals now extinct in the regions where their relics are found; others are still in progress, connecting the present with the past; while some are now far removed from the agencies by which they were formed—the rivers having shifted their channels to give birth to newer formations.

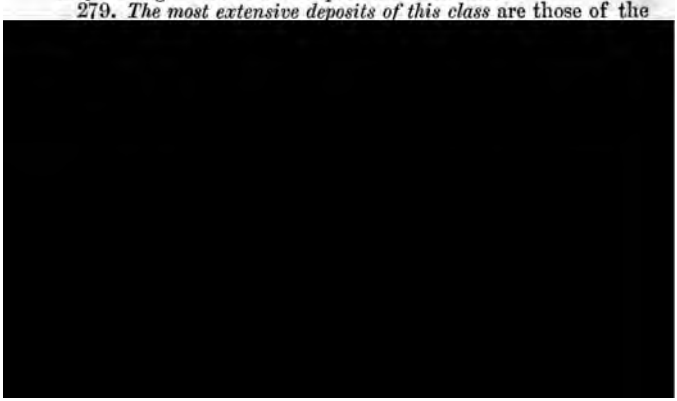
DELTAS AND ESTUARY DEPOSITS.

277. *Of modern deposits, those formed in estuaries are the most perplexing to the geologist*, on account of the numerous and often opposite agencies concerned in their production. The prevailing agent is the river at whose mouth they are accumulated; and this brings down mud, sand, gravel, vegetable debris, and the remains of terrestrial animals—during quiet periods the most impalpable silt, during inundations the most heterogeneous mixture. Further, the deltas of rivers subjected to periodical inundations constitute, during the dry season, low flat tracts full of swamps, lagoons, and mud islands, which nourish the rankest jungle growth, gigantic reptiles and amphibia, beds of shells, and shoals of fishes. During the wet season many of these plants and animals are swept seaward, or buried *in situ*, by the debris brought down by the current. Again, the sea acts in most of these estuaries, running inland from ten to a hundred miles, and consequently depositing marine detritus and marine organisms amid those of a terrestrial and fresh-water character. The student cannot therefore fail to perceive how very complex the nature of such deposits must be, and how necessary it is to exercise caution in pronouncing what agent or agents were concerned in the formation of any individual layer. As in modern estuaries, so in those which existed in former times, and thus the difficulty arises with respect to the alternation of marine and fresh-water strata in tertiary basins, the mingling of fresh-water with marine organisms in the wealden, and the complication of terrestrial, fresh-water, and marine products among the rocks of the coal measures. Bearing these facts in mind, and carefully studying the formation of modern estuary deposits, the geologist is prepared to account for appearances in the older systems of strata, which would otherwise remain unsolved.

278. *Estuary deposits may be said to consist* of irregular layers of mud, clay, sand, gravel, and vegetable debris, intermingled with organisms of terrestrial, fresh-water, and marine origin. When accumulated to such an extent as to constitute dry land, they form rich alluvial tracts of a level and uniform

appearance, decidedly prejudical to health, but favourable to the growth of the cultivated vegetables. In inland and non-tidal seas, as the Mediterranean, Gulf of Venice, and Baltic, the agency of the rivers prevails, forming deltas and shoals which gradually encroach upon the limits of the seas; but in tidal waters oceanic agencies are also at work, either assisting in the accumulation of estuary silt, or distributing the debris brought down by rivers over areas far removed from their embouchures. The accumulations of this kind now forming are almost as numerous as the streams which enter the sea; but the notice of some of the more extensive is all that the limits of this treatise will allow. And here the student should bear in mind one essential difference between the older formations and those of existing estuaries; namely, that among the former a great uniformity prevails, not only in mineral composition, but in the kind of organic remains which they contain, thus evincing a uniformity of climate and other terrestrial conditions; while among the latter scarcely two deposits present one feature in common. The Ganges, for example, bears down to its delta the spoils of the tropics—palms, canes, tree-ferns, bones of elephants, lions, and tigers; the Nile the scanty aquatic plants of Egypt and bones of the crocodile, the camel, and other domestic animals; the Niger the hippopotamus, rhinoceros, and camelopard of Central Africa; and the Mississippi the pines, buffaloes, elks, and deer of North America. In subsequent ages, should these deposits be elevated into dry land, nothing could be more dissimilar than their organic remains, and yet we know that they belong to one common period of formation.

279. *The most extensive deposits of this class* are those of the



mouth of the *Amazon*, we have less particular information; but it is stated by Captain Sabine, that its sediment discolours the waters of the ocean three hundred miles off shore. This sediment is constantly carried to the north-west as far as the mouth of the Orinocco, and thus an immense tract of swamp is formed along the coast of Guiana, with a long range of muddy shoals bordering the marshes—the whole being gradually converted into dry land. Although on a less gigantic scale, the deltoid deposits of Europe have, even within a very recent period, made considerable accessions to the land. During the last thousand years, that of the *Rhone* has gained upon the Mediterranean from four to six miles. "Notre Dame des Ports," says Mr Lyell, "was a harbour in 898, but is now a league from the shore; Psalmodi was an island in 815, and is now two leagues from the sea; and the Tower of Tignaux, erected on the shore so late as 1737, is already a French mile from it." At the head of the Adriatic, the *Po* and other streams have borne down so much sediment, that "from the northernmost point of the Gulf of Trieste down to the south of Ravenna, there is an uninterrupted series of recent accessions of land more than one hundred miles in length, which, within the last two thousand years, have increased from *ten to twenty miles in breadth.*"

280. *Turning to Africa: lower Egypt is the gift of the Nile;* and Herodotus estimates the sediments borne down by this river to be so abundant, that if diverted into the Red Sea, they would fill it up in ten thousand years. The Nile still transports its annual burden of debris, but the seaward growth of the delta is prevented by littoral currents, which sweep it onward to other parts of the Mediterranean. The *Niger* presents one of the best examples of modern deltoid deposits, and affords the geologist much insight as to the manner in which terrestrial, fresh-water, and marine remains become imbedded in the same formation. This delta, as yet so imperfectly examined, ranges along the coast for more than two hundred miles, having a beach of sea-sand slightly elevated above its general level. Behind this beach, stretching inland for more than one hundred and fifty miles, there extend vast expanses of swamp, mangrove-jungle, and mud islands, intersected by creeks, lagoons, and branches of the river. Over this expanse (annually inundated for several months) deposits of sand, clay, silt, and mud are constantly taking place, burying within them the remains of rhinoceroses, hippopotami, crocodiles, &c. which inhabit the jungle, terrestrial animals which the current transports from the high country, and myriads of shell-fish and other aquatic races which abound in the lagoons. Here,

then, we have salt-water agencies prevailing for many leagues inland during the dry season; gigantic amphibia at all seasons; shell-beds and formations of marl in the lagoons; terrestrial animals from inland; jungles and morasses to form lignite; and sand, mud, and gravel to form sandstone and shale. Should a period, therefore, ever arrive when the delta of the Niger shall become habitable dry land, appearances will present themselves perfectly analogous to the tertiary formation, and one by which a flood of light is thrown upon the formation of the coal measures.

281. *The delta of the Ganges*, according to Major Rennel, is considerably more than double that of the Nile, occupying not less than an area of 44,000 square miles. That portion of it which borders on the sea is composed of a labyrinth of rivers and creeks, all filled with salt-water, except those immediately communicating with the principal branch of the river. This tract alone, known by the name of the Sunderbunds, is equal to the whole principality of Wales; but from its recent alluvial character, is subject to numerous shiftings, though ultimately settling down and shoaling up the Bay of Bengal. The quantity of sand and mud brought down by the Ganges is so great, that the sea only recovers its transparency at the distance of sixty miles from the coast; thus not only adding new material to the shoals and islands of the Sunderbunds, but forming immense tracts of submarine strata at various depths from four to seventy fathoms. As Egypt is said to be "the gift of the Nile," so may the great plain of China be considered as the gift of the *Hoang-Ho*, the *Kiang-Koo*, and their tributaries. The same agencies which formed the habitable plain are still at work, gradually shoaling up the Yellow Sea, and

the geologist to infer as to the manner in which the greater portion of the stratified systems were deposited. Their organic remains are numerous; are partially fossilised, or differ little from recent wood, bones, and shells; and all belong to vegetables and animals which have been placed upon the earth since the commencement of the present geological era. Where tidal influences prevail, these remains are chiefly marine; where river inundations predominate, they are fresh-water and terrestrial; while others, as beds of oysters, &c. are of true estuary origin.

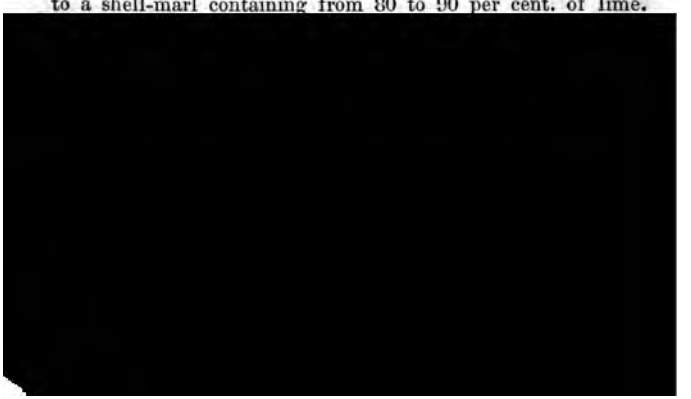
LACUSTRINE, OR LAKE, DEPOSITS.

283. *By lacustrine deposits are meant those accumulations which have been collected in fresh-water lakes* since the present order of things was established. Looking back to certain coal-fields, and to the fresh-water beds of the wealden and tertiary strata, we have almost evidence sufficient to justify the conclusion, that these beds must have been formed in lakes, or at least in estuaries where quiet fresh-water influences greatly predominated. Indeed it is impossible to conceive of a condition of the world without inland lakes, morasses, and swamps, in which aquatic races flourished, shell marl was formed, and peat-moss accumulated. But the boundaries of those ancient lacustrine deposits are now obliterated; and all that the geologist can do is, to judge of the manner of their accumulation, and the nature of their contents, by comparing them with similar deposits now occupying the surface of the earth, or still in progress of formation.

284. *Modern lake deposits* consist of clay-silt, sand, gravel, rolled pebbles, beds of marl, and accumulations of peat-moss. Generally situated in plains or hollows, surrounded by hills, a lake receives the waters and debris of several streams, and its quiet expanse performing the office of a great settling pool, the debris falls down as sediment, and the waters pass off by one outlet purged of all their impurities. This sediment, collecting at the mouths of the streams, forms little deltas, which gradually push themselves forward into the lake; aquatic plants soon spring up on their surface, whose annual growth and decay constitute beds of peat; fresh-water shell-fish and the calcareous debris of the springs and streams collect in certain localities as marl; and these various formations repeated and continued, in process of time shoal up the lake, which forms a flat alluvial tract, swampy at first, but soon acquiring firmness and dryness for the purposes of cultivation. Silted-up lakes are rife in this country as well as in

other parts of the world; they occupy the central and wider parts of our dales and valleys; and though all superficial evidences of the lake be obliterated, the regular manner in which the materials are distributed serve readily to distinguish lacustrine from fluviatile silt. Respecting the extent of surface occupied by lake deposits, it is impossible as yet to form an accurate estimate, though it is evident that the soil of most inland valleys, both in this and in other countries, is composed of it. The prairies of North America, the pampas of South America, and the steppes of Europe and Asia, are regarded by many as the sites of lakes now drained or silted up; and, considering their relation to existing rivers and valleys of drainage, there is ample foundation for the opinion. Considerable tracts of alluvial land are still in progress of formation along the borders of most modern lakes, whose sites, under the double process of silting up and drainage, are evidently destined to become alluvial plains like those to which we have adverted. By *drainage* is meant that tendency which rivers issuing from lakes have to deepen their channels, and thereby not only to lower the level of their parent waters, but also to render them, from their shallowness, more liable to be choked up by aquatic vegetation.

285. *Of the various substances composing lake deposits*, marl is the only one whose formation deserves particular notice. This substance may be looked upon as *the limestone* of the superficial accumulations, just as the chalk, oolite, lias, zechstein, mountain limestone, and cornstone, were the calcareous beds of their respective formations. It occurs in various states of purity, from a marly clay, which will scarcely effervesce with acids, to a shell-marl containing from 80 to 90 per cent. of lime.



are still inhabiting the same lakes and marshes in which the deposit is found. Marl occurs irregularly interstratified with clay-silt, peat-moss, or gravel, and is dug for agricultural purposes in many of the ancient lake-sites and alluvial valleys of Britain.

286. *The organic remains found in lacustrine deposits* are chiefly fresh-water *shells*, such as limnæa, planorbis, paludina, cyclas, mya, cypris, ancylus, &c.; bones, horns, and other portions of *mammalia*, as the stag, elk, deer, ox, horse, bear, fox, beaver; detached skeletons of *birds;* and drift or submerged *plants*, of which oaks, pines, birches, hazels, reeds, rushes, and other vegetation commonly found in peat-mosses, are the most abundant. Human skeletons are occasionally met with; and canoes, stone battle-axes, &c. of great antiquity have been dug up from the silt of Loch Doon in Ayr, as well as from the shell-marl of Kinnordy Loch in Forfarshire. All of these remains, whether plants or animals, belong to races now existing upon the globe, although some genera (as the elk, wild-boar, and beaver in Britain) may have become extinct in the regions where their exuviæ are found.

EXPLANATORY NOTE.

EMBOUCHURE—a term adopted from the French, signifying the mouth of a river, or rather that area over which its current spreads as it enters any sea or lake.

FRESHETS, OR LAND-FLOODS, are sudden risings of rivers, by which they inundate their banks, and carry destruction before them. The term *debacle* (from the French *debacler*, to unbar) is often used instead; but more properly means a rush of water, breaking down all opposing barriers, and carrying away and dispersing fragments of rocks and other debris.

VALLEYS OF EROSION are those which have been formed by the abrading power of water. Rivers having a rapid descent gradually deepen their channels; year after year their banks are undermined, and fall into the current, until they have acquired a slope sufficiently gentle to render them stable; but this stability is only temporary, for the deepening of the channel goes forward, causing the bank to assume a still more gentle slope, till in time a valley of considerable width is formed. Such are termed *valleys of erosion*, in contradistinction to those produced by the silting up of chains of lakes, called *flat valleys*, to those caused by subterranean sinkings, called *valleys of depression*, or to those originally formed by rents and *fissures* resulting from earthquakes.

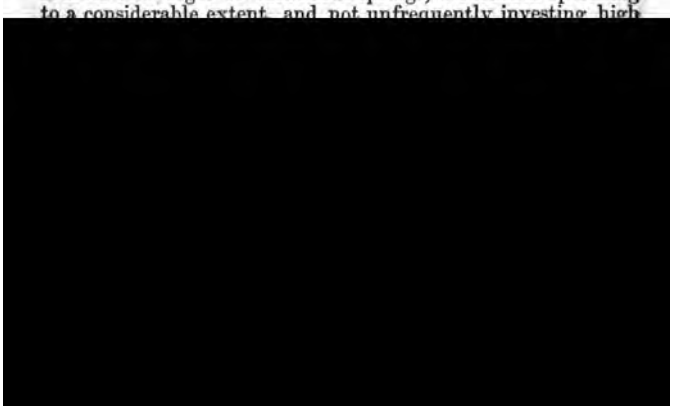
LAGOON (Lat., *lacuna*, a morass)—a term originally applied to those creeks and pools which abound along the coast of the upper Adriatic; but now employed to designate all similar collections of water, in whatever region they occur. Lagoons are sometimes of considerable depth (those enclosed by circular coral islands); but generally they are so shallow (those of deltas) as to emit noxious exhalations.

STEPPES—the Russian name given to the vast system of plains peculiar to Northern Asia. It is synonymous with the *prairies* or *savannahs* of North America; and the *pampas* or *llhanos* of South America. These plains are variously classified, according to the level, undulating, or swampy character of the surface, the kind of vegetation they produce, and other obvious appearances.

SUPERFICIAL ACCUMULATIONS—CONTINUED.

CHEMICAL AND MINERAL DEPOSITS.

287. *Under this head are comprehended* all those superficial accumulations of mineral, saline, or bituminous matter arising from the action of springs, evaporisation, sublimation, or other natural chemical processes. Such products are extremely numerous; but only a few of them exert a perceptible influence in modifying the crust of the globe. *Calc-tuff* and *calc-sinter* are deposited by calcareous springs after the manner described in par. 58. The former, as the name *tuff* or *tufa* implies, is a porous vesicular mass, soft when first deposited, but becoming hard on exposure to the air, so as to resemble marble or alabaster. It is generally of a yellowish-white, and encloses moss, twigs, shells, fragments of bones, and other debris that may be brought within reach of the spring by which it is deposited. The latter, from the German word *sintern*, to drop, or from *sinter*, a scale, is more compact and crystalline, and has a concretionary structure, owing to the successive films which are daily added to the mass. Both are found around the sources and edges of calcareous springs, sometimes spreading to a considerable extent, and not unfrequently investing high

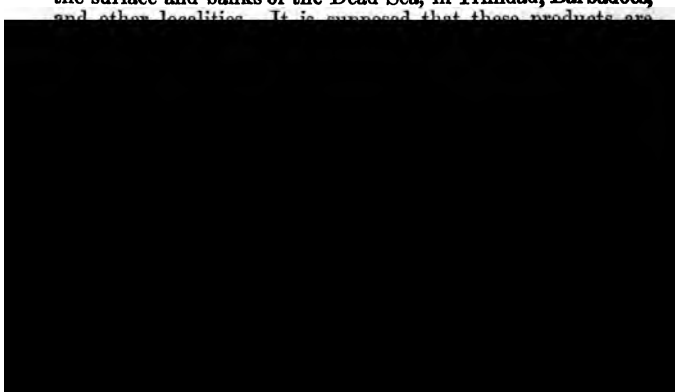


formed by the river Anio at Tibur, near Rome, at San Vignone in Tuscany, and in other parts of Italy. It collects with great rapidity, and becomes sufficiently compact in a few years to form an excellent building stone. "A hard stratum," says Mr Lyell, "about a foot in thickness, is obtained from the waters of San Filippo in four months; and as the springs are powerful, and almost uniform in the quantity given out, we are at no loss to comprehend the magnitude of the mass which descends the hill, which is a mile and a quarter in length, and the third of a mile in breadth, in some places attaining a thickness of 250 feet. To what length it might have reached it is impossible to conjecture, as it is cut off by a stream which carries the remainder of the calcareous matter to the sea." Tavertine is a light, porous, or concretionary rock, well adapted for arches and other structures where weight is objectionable; it is for this reason that it has been used in the construction of the cupola of St Peters.

288. *Silicious and aluminous deposits* derived from springs are of very limited extent—those produced by the Iceland geysers, and the thermal waters of the Azores, being the only examples deserving of notice. According to Dr Webster, the hot springs of the Valle das Furnas, in the island of St Michael, rise through volcanic rocks, and precipitate considerable quantities of silicious sinter. Around the circular basin of the largest spring there are seen alternate layers of coarse sinter mixed with clay, including grasses, ferns, reeds, &c. in different states of petrifaction. Wherever the water has flowed, sinter is found rising eight or ten inches above the ordinary level of the stream. The herbage and leaves are more or less incrusted with silex, and exhibit all the successive stages of petrifaction, from the soft state to a complete conversion into stone; but in some instances *alumina* is the mineralising material. Fragments of wood, and one entire bed, from three to five feet in depth, composed of reeds common to the island, have become wholly silicified; and a breccia is also in act of formation, composed of obsidian, scoriæ, and pumice, cemented by silicious sinter. The same kind of appearances are produced by the geysers of Iceland and several other thermal waters. Where alumina and silica are held in solution by the same spring, the deposit produces an admixture called *tripoli*, so named from Tripoli in Barbary, where a similar compound of silica, alumina, and oxide of iron is abundantly obtained for polishing purposes. All the varieties of tripoli do not seem, however, to be derived from the same source; for Ehrenberg has found the flinty portion of several varieties to be composed of the silicious coverings of animalcules. The fact of hot springs

holding silica in solution, its converting organic matter into flint, and forming layers of tripoli and sinter, is of high importance to the geologist, as it furnishes him with data to reason respecting the origin of the chalk-flints, the occurrence of layers and nodules of chert in limestone, and other appearances among the older stratified systems.

289. *Bituminous exudations*—that is, springs of naphtha, petroleum, &c.—are very abundant in some countries, forming pools of fluid pitch and consolidated masses of asphalte, and impregnating layers of sand, clay, &c. so as to render them inflammable. Naphtha, the most limpid of the bitumens, is found exuding from the earth upon the shores of the Caspian and some other Eastern countries. Near the village of Amiano, in the state of Parma, there exists a spring which yields this substance in sufficient quantity to illuminate the city of Genoa, for which purpose it is employed. It is generally of a yellow colour, and is readily distinguished from other bitumens by its peculiar odour. Springs of *petroleum*, or rock oil, are found in Modena, Parma, Sicily, and other parts of Europe, in Syria and Persia, in the Burman empire, in Texas, and in Barbadoes, whence the appellation *Barbadoes tar*. It is a brown thickish liquid, and in this state readily mingles with loose rocky substances, so as to render their mass bituminous. On exposure to the air it becomes viscous or slaggy, and then constitutes *mineral pitch*, of which the lake of Trinidad, and that of Jefferson county, Texas, are well-known accumulations. *Asphalte* differs from mineral pitch in being so much consolidated as to be rendered brittle. It is found on the surface and banks of the Dead Sea, in Trinidad, Barbadoes, and other localities. It is supposed that these products are



extensively employed as a solvent for caoutchouc, and is also occasionally used as a substitute for oil in lamps.

PEAT-MOSSES—JUNGLE—VEGETABLE DRIFT.

291. *Modern vegetable formations* are commonly distinguished as subterranean forests, peat-mosses, jungle, and vegetable drift, though it must be evident that in many cases no real distinction can be drawn between them. *Submarine forests* have been already noticed (par. 265) as evidences of terrestrial submergence; *subterranean forests* are those accumulations of trunks, branches, and roots which occur inland, apparently produced by the inundation and subsequent silting up of low-lying tracts, in which trees flourished abundantly. But as the subsequent silt is most abundantly composed of aquatic and other peat-forming plants, subterranean forests and *peat-mosses* may be regarded as depending upon the same agency for their production. It must be remembered, however, that peat-bogs and mosses of very great extent are to be found in northern countries entirely destitute of trees, having been formed by the annual growth and decay of the *sphagnum palustre* and other marshy vegetation. With respect to the amount of vegetable matter derived from tropical *jungles*, no accurate information has yet been obtained, though analogy would warrant the conclusion that the result is too important to be overlooked by geologists. The same may be said of *vegetable drift*, of which the rafts of the Mississippi, already adverted to, afford a striking example. It is therefore to subterranean forests and peat-mosses that the attention of the student is chiefly directed, these being by far the most extensive of modern vegetable formations.

292. *Subterranean forests* are found in estuaries now silted up, in ancient lakes, and under ordinary peat-bogs. When they occur in estuaries or in low alluvial lands adjoining the sea, they would seem to have been drifted from inland by river inundations; for most of the trunks and branches lie in such a position as to forbid the supposition that they grew in these situations. "A very interesting case of this kind," says Professor Phillips, "was exhibited some years ago by the deep cutting of a canal connected with the Aire and Calder navigation. At a depth of twelve feet from the surface of the fine alluvial sediment, here occupying the broad valley of the Aire, a quantity of hazel bushes, roots, and nuts, with some mosses, fresh-water shells, and bones of the stag, were met with. In some parts of the superjacent sediments an English coin was found, and oars of a boat were dug up. Where a

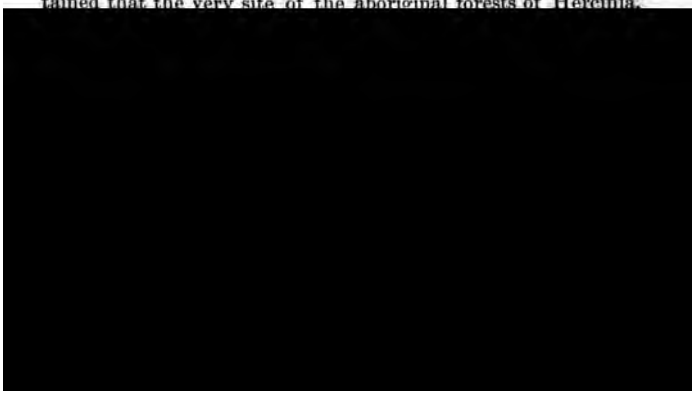
little water entered this peaty and shelly deposit from the adjacent upper magnesian limestone, it produced in the wood a singular petrifaction; for the external bark and wood were converted into carbonate of lime, in which the vegetable structure was perfectly preserved. In like manner some of the nuts were altered; the shell and the membranes lining it were unchanged; but the kernel was converted into carbonate of lime, not crystallised, but retaining the peculiar texture of the recent fruit. In this particular case no reasonable doubt can exist that the peaty deposit, full of land mosses, hazel bushes, and fresh-water shells, was *water-moved*, and covered up by fine sediments from the river and the tide." As with the example now quoted, so with numerous accumulations of trunks, roots, and branches of trees found in silted-up estuaries and in heads of bays both along our own coasts, the shores of the Baltic, and other sea-boards. Most of them have evidently been drifted thither by rivers and tidal influences, although forests in some low tracts may have been overthrown and buried by inundations of the sea. When subterranean forests occur beneath lake deposits, or under ordinary peat-bogs, they point to causes by which the drainage of low woody valleys has been choked up, and their surfaces covered with water, so as to destroy the trees, and bury them by subsequent accumulations of silt and peat-growth.

293. *Peat—or turf, as it is often called—is a natural accumulation of vegetable matter*, varying in age from last year's growth to that which was formed several thousand years ago, and in appearance from a loose fibrous mass of a brown colour to a dark and compact substance resembling lignite or brown coal. It is forming in all marshes by the annual decay of aquatic

lated under certain conditions and in particular localities. They are to be met with in almost all temperate and cold moist countries, whether in the northern or southern hemisphere. They occur abundantly in Scotland and England, and constitute a large proportion of the surface of Ireland. They occupy vast tracts in the Netherlands, Germany, and Russia, as well as in North America and Canada, and are to be found in insular regions, as Shetland, Iceland, and the Falkland Islands. Of the absolute surface occupied by peat, we have no accurate estimate; but some idea of the geological importance of the formation may be formed from the fact, that one of the mosses on the Shannon is fifty miles long, and from two to three in breadth, while the great marsh of Montoire, near the mouth of the Loire, is not less than fifty leagues in circumference. Some of the Scottish mosses have been dug for fuel to the depth of twenty feet, and many in Ireland are reckoned at twice that thickness. It must be borne in mind, however, that nearly one half of the bulk is made up of water, and that the mass can be reduced by compression to less than a fifth of its original thickness.

294. *The formation of peat*, as has been stated, is confined to moist situations, where the temperature is low, and where vegetables may decompose without putrifying. It is thus found in swamps, and on declivities where springs abound, almost entirely composed of marsh plants; in the sites of ancient lakes, covering layers of gravel, marl, silt, &c. and mingled with earthy impurities; or in low tracts whose drainage has been choked, burying, and in part formed of, the trunks and branches of trees which flourished upon those spots previous to their inundation. It increases with astonishing rapidity, instances having been known where fifteen inches in thickness had been formed in twenty years. Being light and spongy, fully half its bulk is composed of water, and this retentive quality enables new races of plants to flourish long after the surface of the moss has been raised above the drainage-level of the flat in which it occurs. When the mass has sufficiently accumulated to change its character from that of a shaking morass to a firm peat-bed, the marsh plants die out, and are succeeded by heath and other vegetation, which carry on the process of accumulation at a less rapid but still perceptible rate. Such is the ordinary mode of peat-growth, concerning which there can be no difference of opinion, for many of the accumulations are still in progress; but respecting those collections of trees which are often found buried in the mass, geologists are far from being agreed. From the varied situations in which such collections occur, as well

as from the different positions in which the trunks are found in the mass, it is evident that different agencies have been at work in their aggregation. In river valleys, the trees sometimes appear to have been drifted, and subsequently silted up and covered by peat-growth; in general, however, they have evidently grown where they occur, and been prostrated either by natural or artificial causes. If, for example, the drainage of a wooded valley were obstructed, so as to render the soil wet and swampy, the further growth of the forest would be checked; the trees, deprived of their firm anchorage in the ground, would be easily overturned by winds; and as they were prostrated, grasses, reeds, and marsh plants would spring up through their branches, and grow rank upon the nourishment afforded by their decay. This prostration of trunks and matting of vegetation would further obstruct the drainage of the waters, so that in process of time the whole of the trees would be overturned, and the valley converted into a swampy morass. In such a morass peat plants would luxuriate till, by their own growth and decay, they reached a height beyond that of the drainage-level, when their accumulation would cease, and a peat-moss be completed perfectly analogous to many of those in Ireland and Scotland. The same result would follow whether the trees were prostrated by natural or artificial causes; and there is evidence afforded by the trunks in many localities that they were felled by man at no very distant era. In the peat of Hatfield Chace, for instance, Roman coins and axes have been found, some of the latter still fixed in the wood; a medal of Gordian was found thirty feet deep in peat at Groningen; and De Luc has ascertained that the very site of the aboriginal forests of Hercinia,



before they were fully enveloped in peat-growth; showing clearly that though the whole face of a country were covered by prostrated forests, it would only be in marshes and peat-forming hollows that the trunks could be preserved from utter decay.

295. *Respecting the antiquity of peat-mosses*, we can form a tolerably correct idea from the nature of their imbedded fossils. The most ancient have been formed since the sea and land received their present configuration, and since the latter was peopled by those animals which now inhabit it; for from none have we well authenticated specimens of greater antiquity than the existing elk, deer, wild ox, buffalo, &c. Indeed the greater proportion of European morasses are of comparatively recent formation, yielding the canoes and skeletons of the hair-clothed aborigines—the coins, axes, and other implements of their Roman invaders—the bones and horns of the elk, deer, ox, and other animals with which we are still familiar. Many have even been formed, as it were, but yesterday; for we learn that the overthrow of a forest by a storm about the middle of the seventeenth century gave rise to a peat-moss near Lochbroom in Ross-shire, where, in less than half a century after the fall of the trees, the inhabitants dug peat. Whatever be their relative antiquity, they are all possessed of great interest, from the evidence which they afford of the rapid accumulation of vegetable growth, and from the perfect manner in which their tannin or antiseptic principles have preserved the remains of man and the lower animals. We cannot look upon the vast collection of trees which they contain, without being reminded of a period when Britain was clothed with gigantic forests; on the rude stone hatchets, canoes, and skeletons of men clad in skins, without reverting to the condition of our earlier ancestors; or on the coins, arms, and other implements of the Romans, without associating therewith the means by which a rude and barbarous country was reclaimed to culture and civilisation.

296. *The economical applications of peat* constitute one of its most important features. Cut in rectangular pieces, and dried by the heat of summer, it forms in many districts the principal fuel, not only for domestic use, but for burning lime, heating corn and malt kilns, distilling alcohol, &c. To facilitate the process of drying, the water is sometimes pressed out of the square pieces by a compressing machine, which also renders the material more compact and durable in the fire. Peat is occasionally charred by a smothered combustion, which makes it a more suitable substitute for coal or coke in the smelting of iron and similar purposes. Attempts have also

been made to extract tannin from its mass, to be used instead of oak and larch bark in the preparation of leather. Decomposed peat forms an excellent manure for certain soils, and is now extensively employed in modern agriculture.

SHELL-BEDS, CORAL-REEFS, &c.

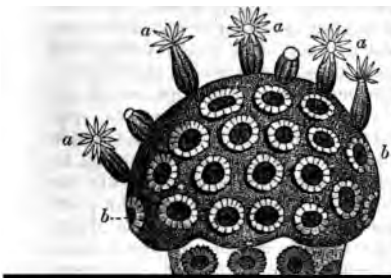
297. *The animal accumulations of the present day*, like those of former eras, are chiefly discernible in the exuviæ of shell-fish and coral animalcules. It is true that the remains of fishes, insects, birds, and mammalia, are constantly being entombed in the deposits now taking place; but, in point of quantity, these are too insignificant to constitute an independent stratum. Such remains must not, however, be overlooked, as their presence in any deposit will indicate to future geologists the condition of the world under which the animals flourished, just as the fossils of older formations are the characters by which we can interpret the conditions of the past. Besides the gradual entombment of organisms which takes place in the ordinary course of nature, there are extraordinary causes by which hundreds and thousands of living beings are destroyed and buried in common ruin. The desolation of populous cities by earthquakes, the destruction of flocks and herds by similar catastrophes or by river inundations, the death of shoals of fishes by submarine exhalations, the drowning of clouds of locusts, and the like, will present curious appearances in the accumulations in which they are imbedded; and it is necessary that the student should bear such possibilities in mind, otherwise he might be unable to account for peculiar aggregations of fossils in older strata.

in the muddy bottoms of tidal estuaries, where the latter often form beds of two or three feet in thickness, and several miles in extent; while the oyster, at no great depth from the sea-shore, covers the bottom for many leagues, to the exclusion of all other genera. Should such estuaries ever be silted up—and there is ample evidence of like occurrences—these shells would form strata precisely analogous to those beds of shell-limestone which are found among the inferior coal measures, the new red sandstone, and other rock formations. Such, in fact, is the case; and in many estuary and lacustrine deposits shell-beds present themselves partially converted into marl and limestone; while in raised beaches they invariably constitute the most interesting phenomena.

299. *One distinction between the position of ancient and recent shell-beds* requires, however, to be specially adverted to. It has been ascertained that various genera of mollusca live at different depths, constituting zones of marine life analogous to zones of vegetable growth on the side of a mountain. By this distribution certain families are littoral, others live at depths varying from 100 to 600 feet, while few or any are found in 1000 feet water. In general terms: testaceous animals are regulated in their distribution by depth, by the nature of the sea-bottom, and by the influence of submarine currents; the number of families is greatest in shallow waters, gradually decreases as we descend, and finally sinks to zero in the depths of the ocean. Such an arrangement corresponds with all our ideas of vitality: shell-fish can no more subsist under the pressure of extreme depth, absence of light and food, than plants can flourish in the thin cold atmosphere of highly-elevated regions. On examining the crust of the earth, however, strata wholly and partially composed of shells are found covered by many thousand feet of rocks; but as the animals by which the shells were formed could not have existed at such depths, we are led to the conclusion that these shelly beds were formed at moderate depths, that the bottom of the sea was subsequently depressed, and received those sediments of which the overlying strata are composed. Strata destitute of organisms do not therefore prove the non-existence of marine life at the time of their formation; they may have been formed at depths so enormous as excluded the mingling of testaceous remains with their component materials.

300. *Coral reefs*, already adverted to in pars. 85 and 86, are chiefly the production of the coral animalcule, and evince, by their magnitude and extent, the powers of organic agency in modifying the form and structure of the earth's crust. As in the case of the sphagnum palustre and other marsh plants,

whose growth and decay went to the formation of peat-moss, so among corals race after race departs, each leaving its stony skeleton as a foundation for the operations of succeeding races, which are destined to make way in turn for still newer generations. According to Ehrenberg, the coral zoophyte may be regarded as a mere secreting membrane, having the power of separating calcareous matter from the waters of the ocean, wherewith to fashion for itself an internal solid skeleton of carbonate of lime. Around and within the radiated pores of this framework the animalcule lives and propagates its kind, expanding itself in the most brilliant colours during its secreting operations, and contracting and withdrawing itself within the pores when alarmed by danger. Although often exhibiting the most beautiful hues—crimson, blue, and yellow—in their native element, the soft parts, when taken from the sea, become nothing more to appearance than a brown slime spread over the stony framework. These zoophytes swarm in incredible numbers, and are of many genera and sub-genera—each species building for itself a structure peculiarly fashioned and decorated. According to their forms the various genera are commonly determined, and thus we have such terms as tree, fan, brain, star, and organ-pipe coral, known to the learned by their synonymes—carvo-

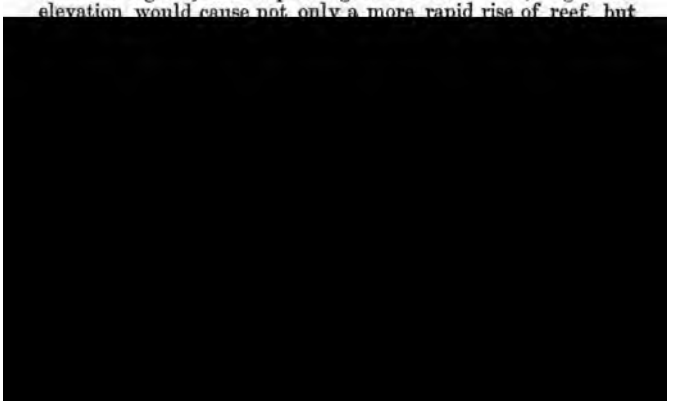


301. *Coral polypes in active operation* are thus described by Captain Basil Hall :—"When the tide has left the rock for some time dry, it appears to be a compact mass, exceedingly hard and rugged ; but as the tide rises, and the waves begin to wash over it, the polypi protrude themselves from holes which were before invisible. These animals are of a great variety of shapes and sizes, and in such prodigious numbers, that in a short time the whole surface of the rock appears to be alive and in motion. The most common form is that of a star, with arms or tentacula, which are moved about with a rapid motion in all directions, probably to catch food. Others are so sluggish that they may be mistaken for pieces of the rock, and are generally of a dark colour. When the coral is broken about high-water mark, it is solid hard stone ; but if any part of it be detached at a spot where the tide reaches every day, it is found to be full of polypi of different lengths and colours ; some being as fine as a thread, of a bright yellow, and sometimes of a blue colour. The growth of coral appears to cease when the worm is no longer exposed to the washing of the sea. Thus, a reef rises in the form of a cauliflower till the top has gained the level of the highest tides, above which the animalcules have no power to advance, and the reef of course no longer extends upwards."

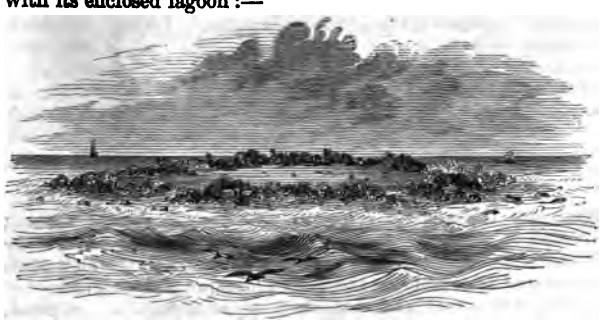
302. *The composition and construction of coral reefs*, though effected chiefly by lime-secreting zoophytes, are still owing, in a great measure, to the promiscuous aggregation of marine debris. As produced by the zoophyte, coral is almost a pure carbonate of lime, soft and porous at first, but gradually becoming so hard and compact as to be used in the South-Sea islands for building. During its formation, however, it encloses shells, fragments of drift-coral, sea-weeds, star-fishes, sea-urchins, drift-wood, and the like ; and these being cemented in one mass by the growth of new coral, as well as by the infiltration of dissolved carbonate of lime, the rock presents a brecciated appearance extremely analogous to some older limestones. Where reefs have been upheaved by subterranean agency, and are now found on the sides of hills partially overlaid by volcanic tufa, the coral stone has a sparry semi-crystalline aspect, thus presenting the geologist with almost every gradation of limestone, from the soft chalky mass of yesterday's secretion to the compact texture of primary marble.

303. *The formation of coral islands* is effected in the following manner :—The polypes having attached themselves to the rocky bottom—say on the summit of some submarine ridge —proceed to build upward and around, till the reef remains

almost dry at low-water level. Here they leave off building in an upward direction, but still proceed seaward, increasing the breadth of their structure, and gradually bringing these additions up to the surface. A continuous mass of calcareous matter is now seen, composed principally of coral, but also abundantly of shells, fragments of crustacea, and other sea-drift. As the waves break upon the new elevation, fragments are detached and thrown up, shells and coral sand are washed upon the reef, and these being cemented together by calcareous matter, form a low ridge exposed to the influences of sun, winds, and rains. In this state rents and fissures take place in the mass, new fragments are detached by the waves, and piled still higher; a perpetual rubbing and grinding of the fragments produces calcareous sand, which is gradually drifted upwards and inwards, filling inequalities, and forming in sheltered recesses a narrow beach. Upon this new territory sea-birds alight, nestle, and leave their droppings; seaweeds and other marine drift are added; a scanty soil is formed; seeds are drifted or borne by birds from the adjacent continents; plants spring up, and in course of years clothe the infant island with vegetation. By this time strayed land-birds have made it their home; insects and reptiles are carried thither upon drifted trees, either alive or in the larva or egg state; and lastly, man appears, and takes possession of the gradually-increasing soil. Such a mode of formation supposes no elevation or submergence of sea-bottom by volcanic action. But in the Pacific, where coral reefs are most extensively developed, subterranean movements are frequent—elevating in some regions, and depressing in others. Thus, a gradual elevation would cause not only a more rapid rise of reef, but



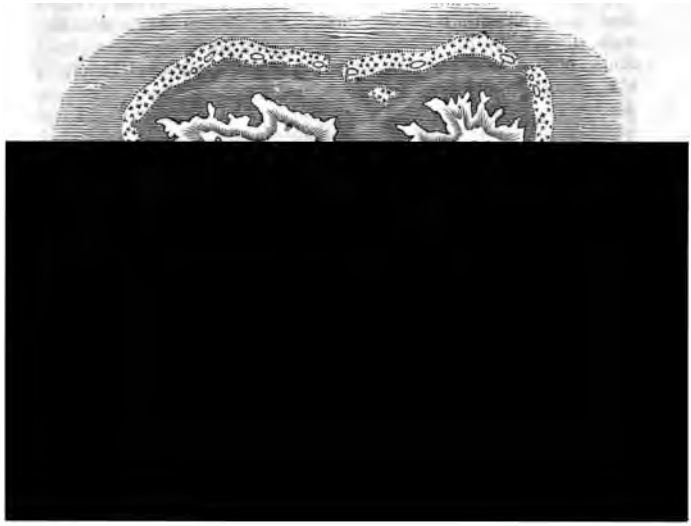
by Mr Stutchbury in the following order:—1. *Circular*, consisting of a strip or belt encircling a lagoon, which communicates with the main ocean by one or more channels; 2. *Flat*, consisting of a tabular, oval, or irregularly round mass, not intersected by channels or lagoons; 3. *Long-narrow*, consisting of long narrow ridges or islands, with cross channels at irregular intervals; 4. *Encircling high land*, but separated from it by a deep concentric channel, with several openings into the main sea. To account for these peculiar configurations, which are very persistent over the whole of the Pacific, various hypotheses have been advanced, all more or less involving the idea of subterranean movements, to which that region is known to be subjected. *First*, Circular reefs or *atolls* are supposed to be founded upon submerged volcanoes—the edges of the crater forming a basis for the coral, and its interior depth the lagoon. The coral islands of the dangerous Archipelago are all of this kind, and consist of circular belts from 400 yards to one mile across the ring, which always enclose a lagoon. They are seldom raised more than four or six feet above the water; are abrupt towards the ocean, which rapidly deepens to more than 100 fathoms; vary from two or three to 150 miles across; and are intersected by deep channels, which allow a free communication between the ocean and the lagoons. The bottoms of the latter are often strewed with dead shells and fragments of coral; sometimes contain smaller reefs, and give birth to numerous corallines, sponges, and shell-beds. The subjoined engraving represents the atoll form, with its enclosed lagoon:—



Distant view of a coral island, with its enclosed lagoon.

Second, Flat or tabular reefs are founded upon some elevated portion of the sea-bottom; they have no lagoons or channels,

but form solid islands of coral, which in progress of time become covered with sand, soil, and other debris. Reefs of this kind often exhibit lines of stratification in their mass, owing to the drifting of sand, shells, &c. over their flat surface during the time of formation. *Third*, Long narrow reefs, which are of common occurrence, are evidently founded upon submarine ridges, interrupted by irregularities and depressions—such depressions causing the channels or gaps by which they are intersected. Many of this class are of great length: Captain Flinders describes one on the east coast of New Holland not less than 350 miles, unbroken by any channel. *Fourth*, Reefs encircling high land, but separated from it by a narrow channel, indicate a submergence of the islands which they surround. At their commencement they must have been in connexion with the shore; a submergence, however, would remove them from it, inasmuch as the waters would cover them, and find a new shore farther inland. In their new position, the zoophytes would build upwards, forming perpendicular masses separated from the land by a greater or less expanse of water, according to the amount of submergence, and the abrupt or gentle ascent of the land. This class is beautifully illustrated by the reefs which encircle the islands Raiatea and Tahaa:—



formation; so, also, the Indian Ocean between Madagascar and the Malabar coast. Captain Flinders describes the great reef which follows the line of the north-east coast of New Holland as more than 1000 miles in length, in course of which there is one continued portion exceeding 350 miles, without a break or passage through it. The thickness of the mass is variable—in some instances less than twenty feet, and in others more than a hundred. Estimating the average at thirty or forty feet, and taking into account the vast length to which coral ridges extend, they constitute an amount of calcareous matter equal to any of the older limestones, the carboniferous alone excepted.

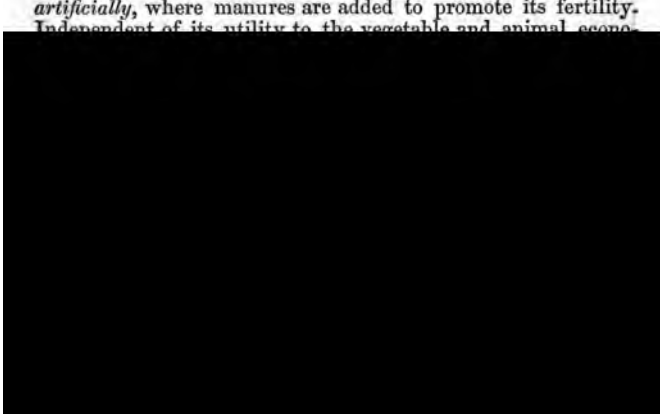
306. *The growth of coral* is by no means rapid; for objects long submerged have been dredged up merely covered with a thin incrustation. It is stated in Captain Beechey's Expedition to the Pacific, that no positive information could be obtained of any channel having been filled up by coral within a given period, and that several reefs had remained for more than half a century at about the same depth from the surface. By others, it has been estimated that the increase of a reef is generally from four to six inches in one hundred years; but this is little better than conjecture; for although the growth of coral by itself be a comparatively slow process, yet, by the accumulation of shells, broken coral, and other drift, a reef may augment at a more rapid rate. Whatever the rate of growth, the process of augmentation is incessant; and thus, in the course of centuries, have the reefs and islands of the Pacific risen above its waters. The student must not, however, confound elevation above the ocean with strict increase of coralline matter; because there is every reason to conclude that vast areas of the Pacific are undergoing a gradual upheave, by which submarine reefs and ridges are continually being brought to the surface, and existing islands further enlarged and elevated.

SOILS.

307. *The superficial coating of the earth on which plants have grown and decayed is properly denominated "soil."* It is chiefly composed of inorganic substances—that is, of clay, sand, lime, &c.—with an admixture of decomposed vegetable and animal matter. There is scarcely a portion of the earth's crust entirely destitute of this covering, unless it be the snow-clad peaks of the loftiest mountains, the newly-deposited debris on the sea-shore, or the shifting sands of the desert. However slight the admixture of organic matter may be, its presence

constitutes soil, beneath which is the *subsoil*, comparatively or altogether without such admixture, and therefore justly classed as clay, sand, gravel, lime, or mixed earth, as the case may be. Soil subserves most important purposes in the economy of creation: without it there could be no succession of vegetation; without a succession of plants terrestrial animals could have no subsistence.

308. *The formation of soil* is of easy comprehension. Suppose a tract variously composed of clay, sand, lime, and other primitive earths to be elevated above the waters, its mass would soon become dry and compact, and being alternately subjected to the sun and showers of summer, and to the frosts of winter, its superficies would be rendered loose and friable. Over this expanse birds would fly and animals roam, mingling their droppings with the earth, and adding their carcases and other exuviæ; the winds would carry the seeds of plants from other regions, and these springing up, would clothe patches of the waste with a scanty vegetation. Mosses, lichens, and other lowly forms would spread over the rocks and gravel, the arundo arenaria, elymus, &c. over the sands, the sphagnum and other aquatic tribes in the marshes, and grasses on the silts and richer portions. The annual growth and decay of these plants would soon form a covering of vegetable mould, enriched by the droppings and exuviæ of animals which fed upon them; and thus in process of time would the region present varieties of soil capable of supporting the highest forms of vegetation. We see such a formation every day taking place around us; *naturally*, in those districts unreclaimed by agriculture, and *artificially*, where manures are added to promote its fertility. Independent of its utility to the vegetable and animal econo-



inorganic substances, air, and water, furnish chemical compounds of humus, carbon, ammonia, &c.—all of which are essential to the perfection of vegetable growth. Sand and clay being the bulky components of soils, a soil is said to be *sandy* when it contains no more than 10 per cent. of clay; a *sandy loam* if from 10 to 40 per cent. of clay; and *loam* if from 40 to 70 per cent. On the other hand, should the clay average from 70 to 85 per cent., it is denominated a *clay loam;* from 85 to 95, a *strong clay;* and if no sand be present, it is pure *agricultural clay.* The same sort of distinctions are made when lime is present in considerable abundance—5 per cent. of carbonate of lime constituting a *marl*, and 20 per cent. a *calcareous soil.* Where soils are immediately derived from the rocks beneath, they partake of the same chemical character; and where separated by layers of sand, clay, and gravel, they are still influenced in their capacities for moisture by the porous or open texture of the subjacent strata. There is thus an intimate connexion between the deductions of geology and agriculture—a connexion which will be more fully pointed out in a subsequent section.

EXPLANATORY NOTE.

ALABASTER—a white semi-transparent variety of gypsum, or sulphate of lime. It is a mineral of common occurrence, and is manufactured into ornamental vases, and occasionally into small statues. The ancients used it for ointment and perfume boxes.

MINERAL NAPHTHA is generally found of a yellowish colour, but may be rendered colourless by distillation. Its specific gravity is about three-fourths that of water; it boils at 160 degrees; and appears to be a pure hydro-carbon, consisting of 36 of carbon and 5 of hydrogen. It is highly inflammable, and burns with a white smoky flame. A liquid very similar to mineral naphtha is obtained by the distillation of coal-tar.

PROSTRATION OF TREES.—It has been stated that the trunks found in British peat-mosses are most abundantly prostrated towards the east and north-east. This is just what might be expected where the trees have been overthrown by natural forces; for not only are our most prevalent winds from the west and south-west, but our highest and most destructive gales are also from the same quarters.

CORAL.—Some varieties of this substance have long been in request for ornamental purposes—their value depending upon the size, solidity, and colour of the specimen. Black and red varieties are the most highly prized, portions of Sicilian coral having been known to bring so much as eight or ten guineas per ounce. The price, however, is extremely variable, other portions of the same mass selling for less than a shilling a pound. Regular coral fisheries are established in the Straits of Messina, on the shores of Majorca and Minorca, the coast of Provence, and in other parts of the Mediterranean. Abundant supplies are also obtained from the Red Sea, the Persian Gulf, the coast of Sumatra, &c.

SUPERFICIAL ACCUMULATIONS—CONTINUED.

EARTHQUAKES AND VOLCANOES.

310. *The effects produced by earthquakes*, in as far as elevations and depressions of the earth's crust are concerned, have been already alluded to, but the various results by which they are followed require further attention. An earthquake may produce a momentary undulation of the ground, followed by no perceptible result; it may simply elevate one region or depress another; it may be attended by a vast destruction of animal life, and the submergence of forests; it may alter the course of rivers, and produce new shores and beaches; it may create vast tidal waves, which give rise to accumulations of debris; open new springs and fissures, from which issue various products differing from those hitherto known in the district. Innumerable instances of such changes could be cited; a few, however, will suffice to convince the student of the importance of this class of geological agencies:—By the great Chili earthquake of 1822, an immense tract of ground—not less than 100,000 square miles—was permanently elevated from two to six feet above its former level; and part of the bottom of the sea remained bare and dry at high water, with beds of oysters, muscles, and other shells adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia. By an earthquake in 1819, a tract—the Ullah Bund—in the delta of the Indus, extending nearly fifty miles in length and sixteen in breadth, was upheaved ten feet; while adjoining districts were depressed, and the features of the delta com-

in Jamaica, when the whole island was frightfully convulsed, and about 1000 acres in the vicinity of the town submerged to the depth of fifty feet, burying the inhabitants, their houses, and the shipping in the harbour. Such examples might be multiplied indefinitely, even within the limits of the historic period; but enough has been quoted to show the extensive nature of the changes which may have been produced upon the superficies of the globe since the commencement of the current era.

311. *Volcanic forces* act in a similar manner, in as far as they elevate, depress, and break asunder portions of the earth's crust; indeed earthquakes and volcanic throes, considered as subterranean movements merely, produce precisely the same results. But volcanoes, properly so called, act in another and equally important manner in producing geological changes. They elevate the crust into long continuous ridges or mountain chains, form isolated cones, and discharge accumulations of lava, scoriæ, ashes, loose stones, and other igneous debris. The same effects have been produced by igneous forces in all ages, as are amply evidenced by the *granitic* rocks of the primary, and by the *trappean* eruptions of the secondary and tertiary epochs. *Volcanic* rocks represent the igneous products of the present era, and are associated with the superficial accumulations, just as the older traps are with the coal measures, oolite, and chalk strata. The granitic and trap rocks occur either as disrupting, interstratified, or overlying masses; so do the volcanic: the former cover extensive districts, and form vast mountain ranges; so do also the latter, as will be seen by an enumeration of some of the more celebrated volcanoes. In Europe there appears to be three centres of volcanic action—namely, that of the Levant, to which Ætna and Vesuvius belong; that of Iceland, represented by Hecla; and that of the Azores. In Asia there is abundant evidence of volcanic action on the borders of the Mediterranean, the Black Sea, the Caspian, and the Persian Gulf; while along the eastern borders of that continent there is a range not less than 5000 miles in length and 250 in breadth, including Sumatra, Java, the Eastern Moluccas, and the Phillipine Islands; the same range bearing farther northward, though less distinctly, for several thousand miles, and terminating in the volcanic cones of the Aleutian isles. The whole extent of the two Americas is also traversed by a volcanic range, manifesting itself by eruptions along the whole line, from the Rocky Mountains through Mexico and the Andes, onward to Patagonia and Terra del Fuego. The islands of the Pacific further attest the presence of similar forces; as do those—

namely, the Canaries, Cape de Verd, Ascension, St Helena, Madagascar, Bourbon, &c.—which surround the continent of Africa. In these centres of igneous action many of the volcanoes are *extinct*, others are merely *dormant*, while many are incessantly *active*.

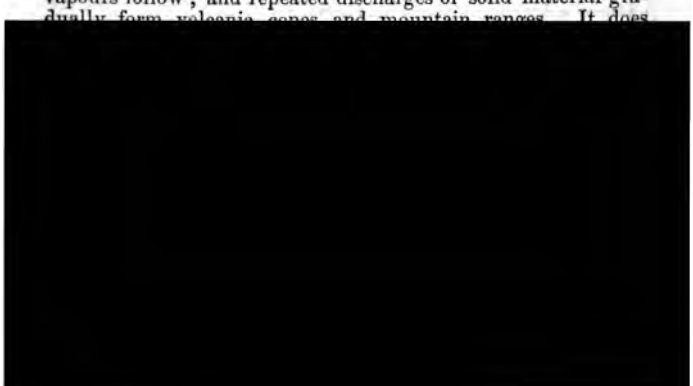
312. *Passing over the disruptions produced by volcanic forces, some idea of their importance in adding to the rocky material of the earth's crust* may be gleaned from what is stated in par. 73, and from the following quotations. In the year 1759 the plain of Malpais, which forms part of the volcanic district of Mexico, was disturbed from the month of June till August by hollow sounds and a succession of earthquakes; and in September flames burst from the ground, and fragments of burning rocks were thrown to a prodigious height. Six volcanic cones were formed, of which Jorullo, the central one, was elevated 1600 feet above the plain, and continued burning, sending forth streams of basaltic lava till the month of February in the succeeding year. None of the other cones were less than 300 feet in height. Twenty years after the eruption, this spot was visited by Humboldt, who found around the base of the cones, and spreading from them as from a centre, a mass of matter 550 feet in height, extending over a space of four square miles, and sloping in all directions towards the plain. A subsequent eruption of this volcano took place in 1819, on which occasion the ashes discharged were so abundant, that they covered the streets of Guanaxuato to the depth of six inches, although the distance of that city from the volcano is not less than one hundred and forty miles. During the eruptions of Sumbawa in 1815, ashes were carried

in the plains rarely more than a hundred, and often not exceeding ten feet." If such be the magnitude of isolated and temporary eruptions, the student cannot fail to perceive how much of terrestrial change must have been produced by volcanic action even during the few thousand years of human history; and can have no difficulty in reasoning from modern igneous forces to those which exerted themselves during the trappean and granitic eras.

313. *The products of volcanoes* are commonly recognised as lava, obsidian, pumice, scoriæ, ashes, mud, steam, and various gases, of which muriatic acid, carbonic acid, and sulphuretted hydrogen are the most abundant. *Lava* is the name given to the melted rock-matter which issues from active craters, and which, when cooled down, forms varieties of volcanic trap, as trachyte, basalt, greenstone, and dolerite, according to the amount of felspar, hornblende, and augite which these rocks respectively contain. *Obsidian*, or volcanic glass, is a glassy lava of a black colour, nearly opaque, and scarcely distinguishable from artificial glass slag. *Pumice* is a light, porous, or vesicular rock, the vesicles having been formed by the disengagement of gases while the mass was in a state of fusion. *Scoriæ, cinders, ashes*, and the like, are of the same mineral composition as the solidified lava, and seem to be produced by the dissipation of the liquid mass by the explosive energy of steam and other gaseous forces. The admixture of water with volcanic ashes forms a fetid clayey mud, which sometimes bubbles out from fissures, or is ejected in currents with considerable violence. *Gaseous products* are in continual exhalation from active craters, or from rents in extinct volcanoes. *Steam* is the most abundant of these; and next in order are the *sulphurous vapours*, from which are derived those deposits of sulphur so extensively employed in the useful arts. The manner in which the rock products arrange themselves is highly instructive, inasmuch as it supplies the geologist with data to reason respecting the occurrence of igneous rocks in connexion with the older stratified systems. Lava issuing from active craters descends in currents from the mountain side, filling up valleys, damming rivers, covering plains, and if in the neighbourhood of the sea, spreading along its bottom, there in turn to be covered by newer sediments. Scoriæ, ashes, and other light material being showered abroad, and borne by winds often to a great distance, are scattered indiscriminately over land and sea, forming layers of considerable thickness, which under the waters are also covered by other deposits. Lava cools irregularly; in one place presenting trachyte of a porphyritic tex-

ture, at another passing into granular greenstone, and not unfrequently assuming a true basaltic structure. In all this the student must see repeated the same processes by which the granitic and trappean compounds were formed, the same modes of arrangement and relation to the stratified rocks; and so can reason with certainty, from what is recent and apparent, to that which is ancient and obscure.

314. *The cause of volcanoes, earthquakes, and other subterranean movements* has been the subject of several theories, but is yet by no means very satisfactorily determined. The most prevalent opinion is that which connects them with one great source of central heat—the residue of that incandescent state in which our globe originally appeared. By this hypothesis it is assumed that the crust of the earth is of various thickness, that it contains vast caverns, and is extensively fissured —primarily by unequal contraction from cooling, and subsequently by subterranean agitations. Through these fissures water finds its way to the heated mass within; this generates steam and other gases, and these exploding, and struggling to expand, produce earthquakes and agitations, which are rendered more alarming by the cavernous and broken structure of the crust, and the yielding material upon which it rests. Occasionally, these vapours make their way through fissures and other apertures as gaseous exhalations, or as hot springs and jets of steam and water, like the geysers of Iceland. On the other hand, when the expansive forces within become so powerful as to break through the earth's crust, discharges of lava, red-hot stones, ashes, dust, steam, and other vapours follow; and repeated discharges of solid material gradually form volcanic cones and mountain ranges. It does



into red-hot matter not unlike certain lavas. This fact has given rise to the supposition that such bases may exist within the globe, where, water finding its way to them, they explode and burn, fusing the rocks among which they occur, creating various gases, and producing caverns, fissures, eruptions, and other phenomena attendant upon earthquakes and volcanoes. As yet, our knowledge of the earth's crust at great depths is excessively limited; we know little of the chemical and magnetic operations which may be going forward among its strata, and we are equally ignorant of the transpositions which may take place among its metallic and earthy materials; but judging from what we do know, this theory, however ingenious, seems by no means adequate to the results produced. It is true that there occurs nothing among the products of volcanoes at variance with its assumptions; but the magnitude, the universality, and the perpetuity of volcanic action point to a more stable and uniform source—that source being the internal heat or residue of that igneous condition in which our planet originally appeared.

EXPLANATORY NOTE.

OBSIDIAN—so named, according to Pliny, from Obsidius, who first found it in Ethiopia. It is a true volcanic glass, of various colours, but usually black, and nearly opaque. In Mexico and Peru it is occasionally manufactured into adzes, hatchets, and other cutting instruments, or fashioned into ring-stones. So closely does it resemble the black slag of our glass furnaces, that in hand specimens it is almost impossible to distinguish the artificial from the natural product. Obsidian consists chemically of silica and alumina, with a little potash and oxide of iron.

SULPHUR, also known as *brimstone*, is a yellow brittle mineral product found in various parts of the world, but most abundantly in volcanic regions. For economical uses, it is chiefly obtained from Sicily, the south of Italy, and the West Indies, though many other districts could yield a profitable supply. It commonly occurs massive, and intermingled with earthy impurities; but is sometimes found crystallised, or as an efflorescence on the sides of fissures, around hot springs, and other subterranean openings. The properties of sulphur are well known: it is a simple combustible, solid, non-metallic; melts at the temperature of 226 degrees; emits a peculiar odour when rubbed; and takes fire at 560 degrees, burning with a dull blue flame of a suffocating odour. It is extensively used in medicine, and for numerous purposes in the arts, as in the manufacture of gunpowder, matches, vermilion, sulphuric acid, &c. Chemically speaking, sulphur is a very abundant product in nature, being found in conjunction with iron, copper, lead, and most of the metallic ores, being also widely diffused among the earths and rocks, as well as entering into the composition of many organised bodies. Though our commercial supplies of the mineral be principally obtained from volcanic districts, yet

it is in the power of the chemist to extract it from iron pyrites (sulphuret of iron), as stated in par. 229.

VOLCANOES which give unremitting or periodical evidence of their being the seats of subterranean fire, are said to be *active;* such as have been in a state of commotion within the historic period, but now afford no symptoms of igneous action, are termed *dormant;* while those concerning whose activity there is no historical or traditionary mention are regarded as *extinct.*

RECAPITULATION.

315. Having described, as fully as the rudimentary nature of this treatise will allow, the various stratified formations, together with their associated igneous rocks, it may be of value now to take a general review of the facts established by geologists in their endeavours towards a completion of the history of our planet.

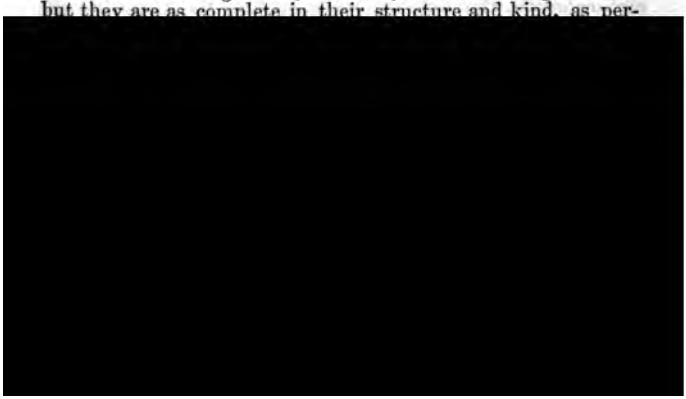
316. *Whatever may have been the constitution of the globe previous to the origin of granite,* we are warranted in concluding that rocks of this class form a floor or basis upon which all the stratified formations recline. Among the granitic rocks there is no evidence of a sedimentary origin, no lines of stratification, no fossils; all of them are massive, and highly crystalline. They upheave, disrupt, and break through the overlying strata in a manner which leaves no doubt of their having been produced by igneous fusion; and such an origin is now assigned to them by almost all geologists. Had granite been a mere metamorphic rock—that is, a product derived from the fusion of sedimentary strata—some evidence of the fact must have been furnished by enclosed fragments of the strata,

bulk of the globe, than the scoriæ on the surface of a glass-blower's furnace. As this process of refrigeration went forward, the gases capable of constituting the atmosphere and water would condense around and upon the earth—the latter occupying the hollows of the crust, and undergoing a rapid evaporisation, both by the internal heat of the mass and the external heat of the sun—and the former constituting a medium for the elaboration of vapours, rains, and other meteoric phenomena. Thus the various operations of Atmospheric, Aqueous, and Igneous agency were set in motion to modify the newly-formed crust, and to produce that long series of changes which it is the province of geology to consider. This constitutes the first era of our planet—a period when it was void of those conditions necessary to the support of vegetable and animal existence.

317. *The products of the agencies now set in motion were the gneiss and mica schist systems.* The rains which fell upon the granitic crust, the streams which descended from its mountains, and the rivers which cut their way through its gorges and valleys, would bear the abraded material to the lakes and seas, there forming layers differing little in mineral composition from the granite whence they were derived. At this period the earth's surface must have been extremely unstable, breaking down in some localities, and being upheaved in others; so that floods of molten granite would occasionally envelop the newly-deposited strata; and thus it is often difficult to separate gneiss from rocks of true granitic character. In process of time, however, the gradual refrigeration of the globe would render the configuration of its crust more stable, and so allow the sedimentary matter to be deposited not only more regularly, but also less intermingled with igneous effusions. Such a state of matters we discover in the mica schists, which are more finely laminated, and more continuous in stratification, than the subjacent gneiss. Of the sedimentary origin of gneiss and mica schist, no one who has examined these rocks in the field can have any doubt; even in hand-specimens the lines of lamination are generally well-marked; the crystals of which they are composed are fragmented and water-worn, attesting the abrading agency to which they had been subjected, while in granite every crystal is distinct and entire. It is true that the rocks of these two systems are of crystalline texture, and must have been subjected to a very high degree of heat—a temperature sufficient to form garnet within mica schist, but not so powerful as to obliterate the lines of deposit in the mass. Another and unobjectionable evidence of their sedimentary origin is afforded by the fact,

that the latter system consists of alternations of various strata, as mica, talc, and chlorite schists, crystalline limestone, and quartz. No vegetable or animal remains have been found in either system; hence the inference, that the earth at this period was not sufficiently cooled down to admit of organic development. This constitutes the second geological era—one during which the dry land and waters were alike devoid of life and vegetation; an epoch of incessant subterranean agitation, as is evidenced by the vast mountain ranges, dykes, veins, and other effusions of granite by which the sedimentary strata are elevated and contorted.

318. *The era of the clay-slate and grauwacke* which succeeded was one during which important events took place in the history of the earth. Mineralogically speaking, these rocks present an immense difference from those of previous systems. Among them the crystalline texture is faint; clayey compounds are derived from the decomposed felspar of the gneiss and granite, arenaceous rocks from the quartz, and conglomerates from the pebbles collected along the shores of the sea. Stratification is now abundantly obvious; and frequent alternations of sandstones, conglomerates, shales, and limestones prevail. All this attests great diversity of action—rivers, currents, tides, and waves; deposition in calm water, and accumulations by violent inundations. These rocks imbed the remains of lowly-organised *sea-weeds*, of *zoophytes*, and of *moliusca*. Here the geologist is, for the first time in the history of the earth, presented with organized forms—beings governed by the same laws of vitality which now regulate plants and animals. These organisms, it is true, are not of a high order; but they are as complete in their structure and kind, as per-

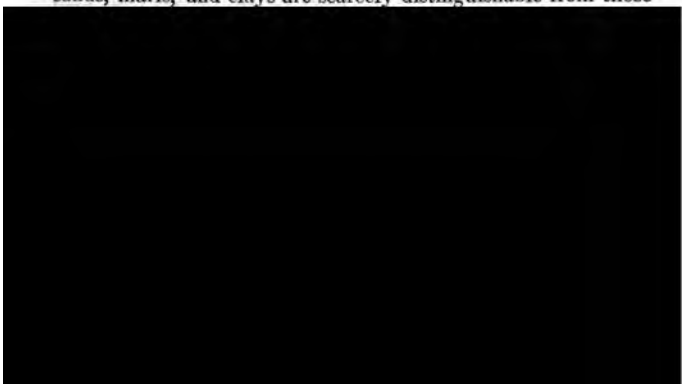


Sandstone—are more decidedly sedimentary than any of the previous systems. They are composed of sandstones, conglomerates, shales, clays, and limestones, alternating with each other in such a manner as to prove the operation of numerous agents during their deposition. At one season the rivers seem to have carried down mud and clay, at another sand of various fineness; in one locality the waves and currents produced pebbly conglomerates along the sea-shore, at another laid down the most impalpable sand, on which is often left impressed the ripple-mark of the receding tide; along some regions of the sea-bottom certain limestones were precipitated by chemical agency, in others it was accumulated by the operations of coral zoophytes. During the deposition of these rocks a change was effected upon the climate and other atmospheric conditions of the dry land, so as to enable it to sustain a scanty vegetation; and here, for the first time in the earth's history, have we evidence of *land-plants* in the remains of equisetums, ferns, and other cryptogamia. The previous *sea-weeds* become more prolific; other genera are added to the *zoophytes* and *mollusca;* and *crustacea* and *fishes* constitute a new feature in the Fauna of the globe. Respecting the land-plants, their remains are too imperfect to afford any just idea of the climate, composition of the atmosphere, or elevation of the land; one thing only is evident, that they are chiefly aquatic, and seem to have flourished in low situations by the sides of rivers, whose waters bore their detached fragments to the seas of deposit. On the other hand, the marine plants are much the same in kind with those of the grauwacke, only flourishing more abundantly, to furnish food to the new increase of herbivorous mollusca. The silurian seas seem to have been crowded in some localities with zoophytes and corals, for certain limestones are almost wholly composed of their calcareous secretions; and among these radiata, *encrinites* make their first appearance. New and gigantic genera are added to the shell-fish; crustacea are introduced in the form of the *trilobite;* an intermediate gradation between crustacea and true fishes in the *pterichthys, coccosteus,* and *cephalaspis;* and perfect fishes in the holoptychius, osteolepis, and other *ganoidia* of the old red sandstone. All this attests a great advance in the vital conditions of the globe—conditions, however, differing so much from those which succeeded, that few of the races created to live under them are to be found beyond the limits of the strata then deposited. This constitutes the fourth period of the world—one of ordinary tranquillity during the formation of the silurian rocks and lower gray sandstones; but still occasionally interrupted by volcanic action, as is evidenced by

close of the new red sandstone epoch, many new genera of fishes and *true aquatic reptiles* were called into being.

322. *The period of the lias, oolite, and chalk* was one of restored tranquillity. The strata, with a few limited exceptions, are eminently marine and estuary, deposited in quiet waters, and undisturbed by igneous agitation. Had we a map of the globe at this epoch, it would present a number of islands and low continents surrounded by comparatively shallow seas; the land supporting a tropical, but by no means exuberant vegetation, and the waters swarming with shell-fish, fishes, and reptiles. An atmosphere such as we now enjoy, a tropical temperature, and abundance of moisture, were the conditions under which new tribes of palms, ferns, cycadeæ, conifera, and a few dicotyledonous trees flourished; and under which chambered shells, naked cephalopods, sea-urchins, star-fishes, new bivalves, ctenoid and cycloid fishes, numerous gigantic *reptiles, marsupial mammalia*, and *monkeys*, were called into existence. In all these forms we discover a nearer approach to existing nature than was made by the Fauna and Flora of previous eras; and yet few, if any, of the genera outlived the chalk formation. The deposition of the oolitic and cretaceous systems constitute another epoch in the history of our planet during which many of its inhabitants died out, and were succeeded by other races better adapted to its progressive conditions. The period was eminently one of rest, distinguished only at its termination by a few local disturbances.

323. *The tertiary strata* were deposited under conditions still more closely allied to those of the present day. With the exception of gypsum and certain limestones, the gravels, sands, marls, and clays are scarcely distinguishable from those

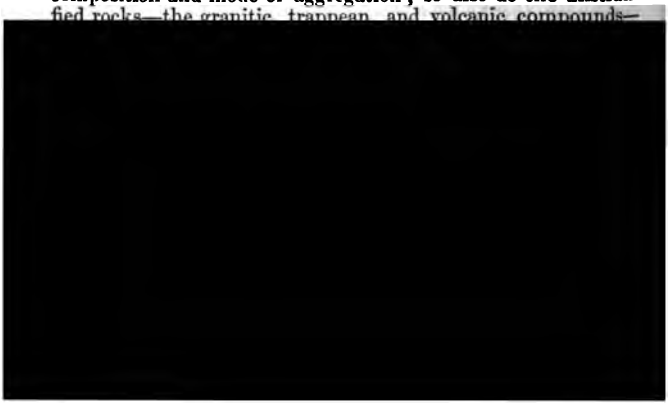


species. The fishes are chiefly of extinct genera, but otherwise closely allied in their forms and mode of life to modern families. Whales, walruses, seals, turtles, crocodiles, are now numerous and indubitable; so that, all things considered, the tertiary era brings us to the confines of existing conditions. This epoch was terminated by a wide-spread and general disturbance, by which the dry land and ocean received their present configuration. This disturbance was accompanied by an almost total destruction of the terrestrial Fauna and Flora; by a decided change of temperature in the regions where the tertiary beds were deposited; and by the production of an accumulation (diluvium) over the greater part of Europe at least, which forms a boundary between the tertiary and current epochs not to be mistaken. With this system the subterranean fires cease to discharge trappean rocks, which had been the invariable products of every igneous agitation from the dawn of the silurian period. It is true that on a small scale there are many of the tertiary traps undistinguishable from the products of modern volcanoes; but, judging them by their general relations and composition, there is as wide a difference between the igneous rocks of the current epoch and the trap, as there is between the trap and the older granitic compounds.

324. *The current era* is that lithologically represented by those superficial accumulations of gravel, sand, clay, marl, peat-moss, shell-beds, coral-reefs, &c. with which every one who moves beyond his own dwelling must be to a certain degree familiar. Many of these accumulations are of great antiquity, and, both in their mineral and fossil characters, blend with the tertiary strata. One fact to be observed respecting the whole of them is, that they are loosely and irregularly scattered over the surface, and have been evidently deposited since the crust received its present configuration. Still, it must be borne in mind that there is no such thing as geological rest—the atmospheric, aqueous, igneous, and organic agencies are incessant in their operations; so that what we denominate "an era," is, in fact, a mere series of progressive movements, whose results present as many points of similarity as will admit of their being classed under one category. Even since the present order of things was established, great changes have been effected; portions of dry land have been submerged, and portions of sea-bottom raised above the waters; lakes have been silted up, rivers changed from their courses, and mountains formed; while organic agency has produced peat-mosses and coral-reefs of astonishing magnitude. We have seen that the Fauna and Flora of other epochs

successively died away with the change of conditions under which they flourished; and so the commencement of the current era was marked by the creation of new orders suited to its peculiar conditions. These are the various races of plants and animals now existing—subjected to the same laws of vitality, but differing in habits, form, and kind from those of other geological cycles. Formerly, the orders, genera, and species were few, with an immense number of individuals under each species; now, individuals are less numerous, while the species, genera, and orders are infinitely more varied and complicated. As far as can be inferred from the discovery of fossils, there has evidently been a progressive development of vegetable and animal life; not progressive in point of perfectitude—for the zoophyte of the silurian seas is as complex and perfect in its structure as those of the Pacific—but progressive inasmuch as higher and more varied orders were successively called into being. This view, borne out by all that has been witnessed in the stratified systems, is confirmed by the current era, which claims for itself still more highly-organised orders of being—these orders crowned, moreover, by the creation and distribution of MAN. In none of the older formations were found any remains of man or his works; these are confined to the most recent and superficial accumulations—to masses of volcanic scoriæ, peat-bogs, and river-sands.

325. *The history of the earth* thus presents a long series of mineral and vital gradations, as yet but imperfectly interpreted by geology. The stratified formations, from the gneiss to the existing surface, bear evidence of these gradations, both in their composition and mode of aggregation; so also do the unstratified rocks—the granitic, trappean, and volcanic compounds—



boar, wolf, and beaver, are now extinct in Britain; and what takes place in limited regions, must also occur, though more slowly, in wider continents. The dodo of the Mauritius, the dinornis and apteryx of New Zealand, are now matters of history; and the same causes which led to their extinction seems hurrying onward to the obliteration of the beaver, ostrich, kangaroo, and other animals whose circumscribed range of existence is gradually being broken in upon by new conditions. Such facts as these, taken in connexion with the numerous superficial changes produced by rivers, lakes, seas, peat-beds, coral-reefs, earthquakes, and volcanoes, have led to speculations as to the conditions which yet await our planet.

326. *Respecting the future history of the globe*, it were vain to offer any conjecture. Subjected as it is to the numerous modifying causes previously described, we know that vast changes are now in progress, and that the present aspect of nature is not the same as that she must assume a thousand years hence. But what may be the character and amount of these changes, what the new conditions brought about by them, or what the races of plants and animals adapted to these conditions, we have no means of determining. This only we are assured of, that whatever vicissitudes may affect the globe, they will be tempered in perfect accordance with the happiness of organised existence: that Supreme Intelligence which has maintained the past will continue to protect and superintend the future.

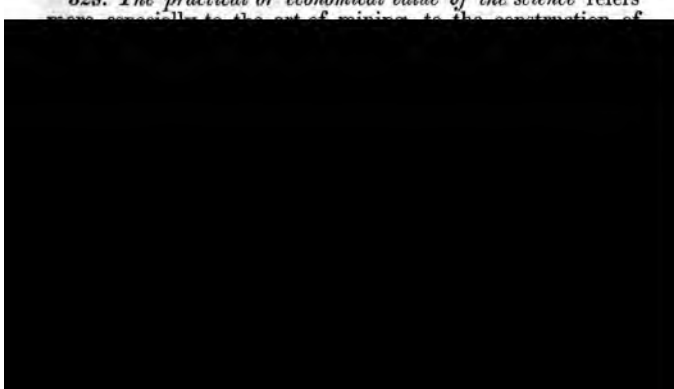
IMPORTANCE OF GEOLOGY.

327. The object of the science being to ascertain the nature of the materials composing the earth's crust, their mode of arrangement, and the causes producing that arrangement, it has at once a *theoretical* and *practical* importance. The former consists in that impetus which it gives to intellectual activity, the wholesome discipline which it confers on the reasoning faculties, those exalted notions of creation which it conveys, the sounder convictions of man's relation to external nature which it imparts, and in the thousand proofs which it establishes of a divine and superintending intelligence. The latter, on the other hand, arises from the economical benefits which it confers on civilised life; from the aid which a knowledge of its deductions affords to the arts of mining, engineering, architecture, and agriculture.

328. *In its philosophical and speculative importance*, geology is second to none of the natural sciences. Depending for

an accurate solution of its problems upon mechanics, chemistry, botany, and zoology, it takes a wider range of investigation than any other individual science; indeed, as a history of the earth, it may be said to embrace the total field of human research. Its study, therefore, calls into activity not only the observing powers to note what actually occurs, but the reasoning faculties to account for the source and mode of occurrence. It is thus liable to be encumbered with the absurd and fanciful theories of imperfect knowledge —theories, however, which gradually disappear before the light of more accurate observation and sounder reasoning. Though essentially aided by the other sciences, it has not left the assistance altogether unrepaid; but has afforded numerous suggestions to the chemist, and thrown additional light on the study of plants and animals by its peculiar fossil forms, which replace, as it were, the lost links of vital gradation. But the discipline which it confers on the reasoning powers is further enhanced by the intellectual pleasure which its investigations afford. The study of existing nature is confined to what is recent and obvious: geology takes a bolder flight, and reveals the successive conditions of the world to the remotest periods of time; and as each era, with its peculiar forms of life and vegetation, is unfolded, what research could be more fascinating or instructive? As in existing nature everything is impressed with proofs of divine wisdom, so in the revelations of geology every fact teems with evidence of the ceaseless agency of the same upholding power.

329. *The practical or economical value of the science* refers

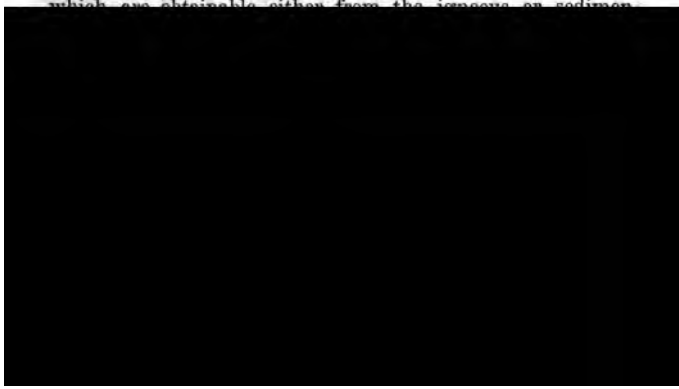


sandstone; he knows, also, that after the commencement of the new red sandstone, coal in workable beds ceases to be found, and that lignite, jet, and brown coal are mere local and insignificant deposits. Besides determining the position in which coal, ironstone, and other useful strata occur, geology can direct the miner through all those obstructions occasioned by faults, dykes, slips, and the like; for even these, irregular as they seem, bear certain evidence of their direction—upthrow or downthrow—which the experienced eye can readily detect. As with the minerals of commerce which occur in strata, so to a certain extent with the ores of lead, copper, tin, silver, and gold which are found in veins and lodes. These veins follow certain courses in relation to the great axis of elevation with which they are associated, are interrupted by cross dykes and veins, are thrown up or down by dislocations—all of which an experienced geologist can determine and map out, so as to save much fruitless waste of labour and capital.

330. *The importance of geology to the civil engineer and architect* is so obvious, that the fact requires little illustration. Possessed of a well-constructed lithological map, on which are delineated the various kinds of strata, their dip, direction, and other particulars, the engineer has a safer and cheaper guide for his direction than the scattered data of the boring rod. He sees at once the nature of the rocks through which his work has to pass—whether common road, railway, or canal; can estimate with certainty the expense of construction, and avail himself of minerals which he knows must lie in the vicinity; while one ignorant of geological truths would blindly pass by such advantages. In fixing a line of road or railway, the informed engineer will avail himself not only of facilities for present construction, but calculate, from his lithological knowledge of the district, for the future benefit of those concerned in the undertaking. In the case of canals, moreover, where retention of water is indispensable, the geologist can effectually aid in the selection of a route, by attending to the nature and dip of the strata, and to the fractures and dislocations to which they have been subjected. He is enabled, from his knowledge of the rocks and their positions, not only to prevent waste of water, but to select a route where fresh supplies can be readily obtained from below. As with roads and canals, so with tunnels, docks, Artesian wells, and other undertakings commonly intrusted to the civil engineer. It is true that such works may often be satisfactorily enough completed without the aid of geology, but undoubtedly a knowledge of its deductions will materially assist,

by conferring a certainty and security on what would otherwise be a mere system of trial and error. The assistance which geology brings to the architect is not quite so obvious; as actual experiment is, after all, the best and only test of a rock's durability. However, by observing the effects of weather, water, and the like, on strata exposed in natural sections, he can readily determine as to their fitness for any particular structure. The amount of waste experienced by ancient buildings is also another safe and valid test; and it is the travelled geologist, and not the mere builder, who can point to the locality, nay, to the very stratum, whence the stones of these buildings were obtained. Thus, both directly and indirectly, the science is brought to bear upon architecture; a fact fully appreciated by the legislature in its appointment of a commission, composed in part of geologists, to determine the rock most suitable for the structure of the new houses of parliament.

331. *The assistance which geology is calculated to confer on the science of agriculture*, constitutes one of the most apparent features in its economical importance. All fertile soils consist of two classes of ingredients—organic and inorganic; the former derived from the decomposition of animal and vegetable matter, the latter from the disintegration of the subsoil or rocks beneath. Without a certain proportion of organic matter, no soil can be fertile; but it is equally true, that without a due admixture of inorganic compounds, all attempts to improve it will be fruitless. These compounds are chiefly clay, lime, silicious earth, and magnesia, with certain salts of iron, manganese, potash, and soda—all of which are obtainable either from the igneous or sedimen-



unbroken clays. Again, land of itself dry and friable may be rendered wet by springs which arise along some line of dislocation. The farmer acquainted with the deductions of geology would cheaply lead off these springs at their source, while he who was ignorant would laboriously furrow-drain his whole field, and find, after all, that his was the less effectual method of the two. Such are mere indications of the assistance which geology is calculated to confer on agriculture—an assistance very apt to be overrated, unless the farmer at the same time avail himself of the discoveries of chemistry and vegetable physiology.

332. *It must not, however, be supposed that the science is of practical value* only to the miner, engineer, architect, and agriculturist; every individual is liable to be more or less assisted by its deductions. The capitalist who speculates in land, the agent who effects sales, the statistician, traveller, and explorer, may all reap direct advantage from the same source. Take, for example, a case of emigration:—Two individuals, possessed of equal capital, set out, say to New Zealand or to the Far West of North America. The one ignorant of geology fixes upon a locality characterised by the beauty of its scenery and the fertility of its soil; the other skilled in the science decides upon a long-rejected lot, of bleak and barren aspect, but rich beneath in coal, limestone, iron, copper, or lead, which his geological knowledge at once enabled him to detect. The former pays a high price for his land, and yearly toils over it to reap therefrom a remunerating harvest; the latter obtains his despised territory for a mere trifle, makes his fortune in the course of a few years, and when roads and canals are constructed around him, re-sells his property for fifty times its original purchase-money. Such instances are by no means of rare occurrence. Even our own country can furnish examples where estates, sold under ignorance of their mineral value, brought only ten or twenty thousand pounds, for which, in less than a dozen years afterwards, an offer of ten times that amount was rejected.

333. *The advantages resulting to civilised life from the cultivation of geology* must be rendered sufficiently obvious even by the above hasty and imperfect outline; and yet it is scarcely half a century since it was recognised as a legitimate branch of natural science. Previous to that period it was obscured by absurd theories, which drew down upon it the imputation of being a visionary and dangerous pursuit; now, by the cautious industry of its cultivators, it is established as one of the most important of human acquirements. It is taught in our schools and colleges, disseminated by treatises

and from lecture-rooms, and especially fostered by every enlightened government. Like most other sciences, it has still a wide field of research before it, many difficulties to overcome, and prejudices to remove; but, linked in connexion with all that is valuable and interesting to man, there is little apprehension for the successful attainment of its object—a complete physical history of the planet we inhabit.

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☞ The figures in the columns beneath indicate the paragraphs of the text in which the particular term or subject is fully explained; and the letter *n* refers to the notes accompanying the section in which the paragraph occurs.

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(New York Times, Jan. 25. 1851.)

Earth in a Chaotic State

I Day, Light created / diffused / & universally / — day & night

II Day, Atmosphere elaborated / This only preparatory / only means to an end / blue vault — clouds — Waters below / conditions of existence — organisms will follow.

III Day, 2 distinct creative acts / dry land appears / & C verdure, grass, herb & tree / And now / twice / God — "it is good"

IV Day, Lights set in firmament. Sun / & moon appear visible / moon & stars / & night / In bodies the light is now concentrated.

Thus far no life.

V / Atmosphere & waters — living things. God blesses

2 creative acts

VI. Morning — creeping things — beasts / afternoon / man

THE END.

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(Dec XII Times, Jan. 55. 1857.)

Earth in a Chaotic State

I Day, Light created / diffused / & universally / day & night &c

II Day, Atmosphere elaborated / This only preparatory / only means to an end / blue vault – clouds – Waters below / conditions of existence / organisms all follow.

III. Day, 2 distinct creative acts / dry land appears / & C verdure, grass, herb & tree / and now / twice / God – "it is good"

IV Day, Lights set in firmament. Sun / & all of vague matter / & visible / moon & stars / & Night / In the bodies / the light is now concentrated.

Must say no life.

V / atmosphere & water – THE END. living things. God blesses & work. 2 creative acts /

VI. Morning – creeping things / beasts / afternoon / man /

intelligent being — 7 v 27 vs. 1 & creation.
In vs. 31. expression, made especially & g cosmogonic process, & it is predicated & every step & process.

Note/ apparent paradox as to light & heavenly bodies/ very difficulty/ often urged against & Word & ✓ & corroborated in/ for modern astronomy confirms the daring postulate/ & pronounced the sun an opaque body, surrounded by a luminous atmosphere. Until within & last half century vulgar observation & scientific systems contradicted/ now/ confirm the scriptures narrative. —

Note/ another paradox. Why should Moses/ if uninspired/ create man & take the woman afterwards & guide/ sublime typical import & creation & man/ Thy & end & crowning complement & & previous creation/ So one day & antecedence & Son of man & & Key & human history/ the accomplishment & & in our race.

Result

1 Moses & & & gloke or ice cov'd waters/ Geology & & & land & emerged & & ocean.

2 Moses & & & dry land & & & M, movement & & & upheaval & land/ Sovereignty/ after 35 centuries. Geology bids us & Scripture literally. Job. 38. 8-11 Ps. 104. 6-9.

3 Moses & — vegetable & animal species & & & & & & Psalm/ Many & abrupt commencements & cessation & organic life/ same story/ No transformation/ no development/ & old species / & annihilated/ new introduced/ sudden & complete — & & & & & eastern dynasty".

4 As & Gen. & 1 2 parallel series/ such — & order of fossil remains. First vegetables — then living things & water/ atmosphere/ & finally on dry land/ page calcined. Now in geology/ & do & far above up to 3d days/ But- coal beds & Silurian & animals/ mammiferæ/ then birds/ Mormian/ then the terrestrial fauna. Where is there a Parsian or Hindoo Cosmogony & & & Bible/ & Geology/ but & 2 do a

The gold region of the Ural ~ 600 miles S. of 52 North lat. is about 150 miles wide.

All the mines (of any value) are rocky matter) & abandoned ~ Beresvosk mine S. Ekaterinoberg

Gold occurs in solid rock in 2 ways 1st disseminated lita iron pyrites & clay slate or garnets & mica-slates 2d in small veins of auriferous quartz, traversing felspathic rocks, & cut thro talcose, chlorite & clay slates.

Proportion of vein stone & gold at Beresvosk averaged 76000 to one.

Auriferous gravel: The proportion & gold to it & favorable conditions occurred between 1 & 76000 & 1 & 48000. Under favorable & refuse & gravel & to gold as 1.536000 to one. Mean produce of gold from gravel as 1 to 384, & Thus to obtain one pound avoirdupois of gold, (256) 172 tons of gravel & must be moved & washed. One piece (1843) 78 lbs found near Minsk, Museum at Petersburgh. 22 oz. found at Wicklow gold mine melted & cast (with presented & Earl of & Museum of Dublin Society !!!) Fermont bought piece 30 oz. weight & & Scotland: Largest pieces & Europe.) Pepita 48 lbs in North Carolina

Jacob estimates the stock of metallic wealth in reign of Augustus, & produce of mines of whole world at a maximum at £385,000,000: that annual loss by abrasion = 1 part in 360: that the ancient mines yielded ¼, & 5th & 8th cent?; that middle ages no more replaced annual waste. He concludes that in 1492 stock of gold & silver in Europe = 1492, when America had discovered, had dwindled down to £34,000,000.

At end = 1599 £130,000,000 circulating medium of Europe, 4 times amount in 1492.

The mines of Europe & America = 17th century, gold & silver to value of £337,500,000.

At end = 1699. circulating medium of Europe = £ 799 less £ 299,000,000, in the century an increase of £150 per cent. - At end of 1809 = £380,000,000.

An increase in 18th century of 28 per cent.

(Since 1699 Jacob estimates loss by abrasion as 1 in 420: Macculloch in consequence of improvements in coinage; 22 parts fine gold (2 of alloy, silver, & ½ copper) estimates annual waste as high as 1 per cent; & loss by wrecks &c. —

At end = 1829 (18 since 1899 excess of consumption, over supply the metallic circulation of Europe is reduced to £313,388,560, diminn = 1-6th in 20 years. The increased produce of metal from Russia, South America &c brought (before California discoveries) total annual supply to a million, or 2 of its amount & mines = S. America, a = zenith = & mexpenly. —

Wide difference between Macculloch & Jacob & & amount = metallic circulation of Europe, & the United States.

(also p. 236)

* (See opposite) See antea, p. 119 + 120 — Macculloch. —

The diamond is easily recognised by putting it in water - for it loses presence its lustre, having & appearance of a bubble of air: whilst all other precious stones lose it. From Memoire Roche Geologique sur la Provence (next page)

de Minas [illegible] au Brésil. Published in the Bulletins de L'Académie des Sciences &c de Bruxelles, 1841 Tom. VIII part I. pp 222-343 / North Brit. Rev. No 35. p. 208

220

Macculloch: estimate. — (in 1846) £ 160,000,000.

Jacob appears to be, (in 1844) £ 298,642,952.

Present produce of S. America = £ 16.000,000.

Siberia & California = £ 7,000,000. more.

But 66,000,000 was lost between 1809 & 1829; in Russia alone in 1829 = 24 millions, but the half-produce was bur. in Sib. in 1809 & the half-amount in 1829 = 12 millions, out of which [illegible] excess in consequence of

require 20 years to restore £ 160. We

may mathematically, if California, produce, £ 4,000,000 of gold annually for 30 years. —

There it is known, as geological information has reached us, that gold is dispersed & altered stated rocks, & the igneous masses to which such alteration is due. Great natural laws, & ground & rocks, & collected & gold & granite found from & veins.

There, doubtless, as elsewhere such rocks are variously [illegible] gold, still, unlike such veins & metals, diminish in productiveness as they are followed downwards. This also another general rule

[redacted]

+ Williams: Wordsworth Lectures, p. 436.

Statement of Sir C. Lyell in close of address at anniversary meeting of Geological Society

One of the objects Mr Logan Director of Geological Survey of Canada has in England of the lowest fossiliferous beds of the Laurentian rocks of North America slabs of rock & slabs exhibiting the tracks & trail of a quadruped, these have, he says, been made by a reptile in all probability allied to the tortoise. The existence of no doubt of large size. Thus even as Robinson Crusoe of the Mesozoic & Cenozoic periods, consistently with, more so than the Mesozoic & Cenozoic periods, peopled and made rich & fair with many vertebrata, of the primeval epoch of Laurentian & shore of the sea: and away in the distance simple but significant hint a crowd of ingenious but unfounded theories & brilliant hypotheses — Lyell. Jahrb. 1857 (See pages anniv. 36, 37) See Athen. 1857, p. 1350 also, 1852, p. 383

Permanence of Kind. — Prof. Owen Lect. at Zoological Society a new species of Mesodactyle of chalk, remarked that as far as the evidence of 3 characterised species goes the organization of the reptiles of the chalk period inclusive had undergone no transmutation — no tendency to pass upwards or higher mixed form of animal. Neither had it in any measure degenerated, but was

had attained the maximum of development of Pr 1 the final disappearance of Sc of the secondary epochs of Geology & Pleiocladacylus & Glyptodon & existence. An allied fish depicted on the walls of Pompeii corresponds specifically & precisely on the shores of living of the Mediterranean. There are fish hieroglyphically sculptured on Egyptian monuments & of characters identify & on the walls of Pompeii locality: and a beautiful illustration of the law of Progress were last evening at the Royal Institution of a masterly exposition of metamorphoses of Animals & Plants. Notwithstanding the substantial metamorphoses of Prof. Owen's frog & monkey — & of the same organism of Haeckel & Pfaffrath

[redacted]

* Whitelaw's Lyell's Elements, p. 436.

Statement of Sir C. Lyell in close of address at anniversary meeting of Geological Society

One of the geologists M. Logan Director of Geological Survey of Canada has found in England & Scotland lowest fossiliferous beds of Paleozoic rocks in North America. Slabs & casts of slabs exhibiting the tracks & trail of a quadruped. Their heavy & long claws & prints very much like those made by a reptile in all probability allied to the tortoise. The existence of such an animal in the Coal period no doubt of great interest. Thus even as Robinson Crusoe found in the sand the print of a man's foot, so the geologist has discovered in the Coal measures of Nova Scotia the footprint of a reptile.

Lyell's Principles of Geology, 1853, p. 1350

Lyell's Address, 1850, 1852, p. 383

Permanence of Kind. — Dr. Owen of the Zoological Society a new species of Mesodactyle in the chalk, remarkable as far as the evidence of 3 characterised species goes for organisation of the reptiles of that period that of the chalk inclusive had undergone no transmutation — no tendency to progress from a lower to a higher mixed form of animal. Neither had it in any measure degenerated, for

(224) The gold region of the Ural
52 North lat. is about 150
all the mines (
abandoned
Gold occurs
iron pyrites
slates 2d in small veins of
traversing felspathic rock
chlorite & clay slates.
Proportion of vein stone
averaged 76000 to one
Auriferous gravel; The
To favourable conditions
76000 & 1 & 48000. Un
refuse gravel &c to gold
Mean produce of gold from
Thus to obtain one pound
(256) 172 tons of gravel
One piece (1843) 78 lbs
22 oz. found at Wicklow gold
presented
Sennant says a piece 30 oz
largest piece

/Radiating & Concentric lines/

...ur (amidst the reticulations) small
...r (discs, or glands) figured, disposed
...s.
...he discs are in single rows, within
... Pinus Strobus
...he entire genus of living (Pinus, w
... of discs occur in one vessel, the
... rows are placed side by side, and

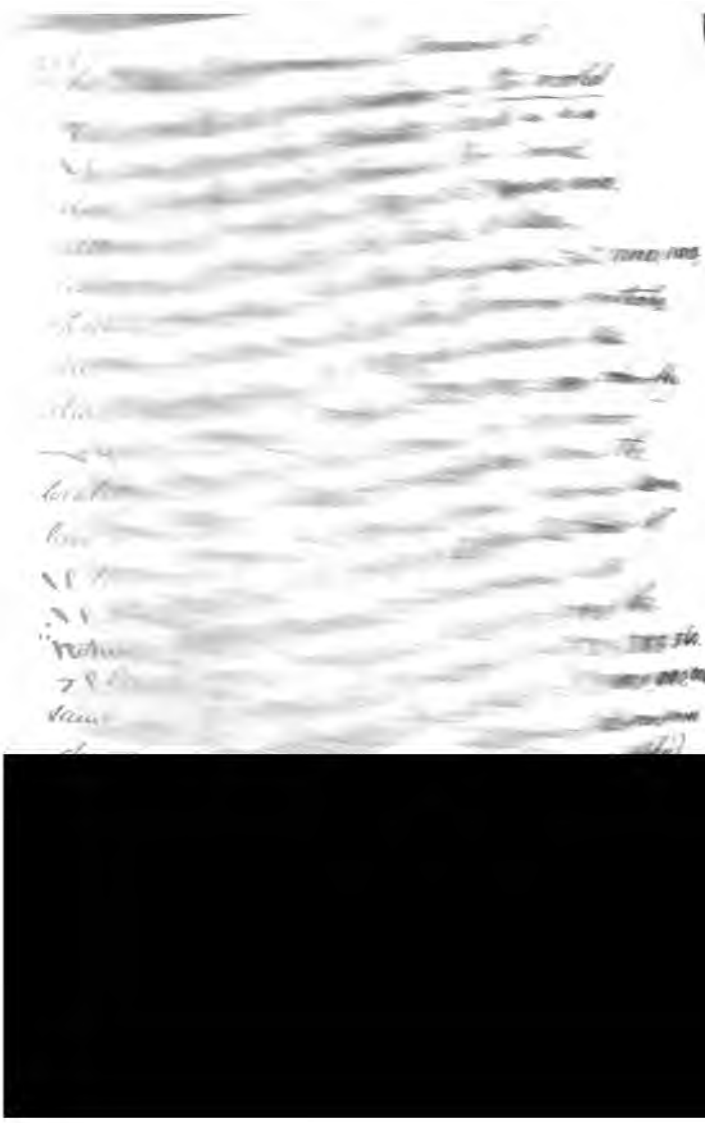
o o
o o
o o
o o /

...number of the rows is never more

... aurorias)
... racaria, the groups of the discs
... in single, double, triple, & sometimes
... rows. They are much smaller than
... Pines, scarcely half their size; and in
... they always alternate in each other
... sections circular but mostly polyg

... counted a row of 4 less than 50 disc
... the 20th part of an inch; the diameter
... not exceeding the 1000th part of an in
... fossil woods & Whitby Jets, when concentr

... 4 forms of very small conif
... & Diamond North Pa

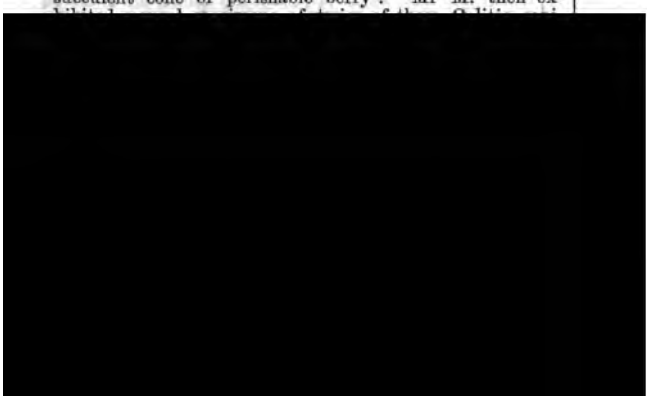


This Society held its monthly meeting on Wednesday last,—Dr Greville in the chair,—when there was a large assemblage of members present, and many visitors.

Mr HUGH MILLER read a paper "On the Oolitic Flora of Scotland," illustrated by a large collection of specimens, exclusively Scotch, and derived chiefly from the Lias of Ross and Cromarty, and the Oolite of Eigg and Sutherland.

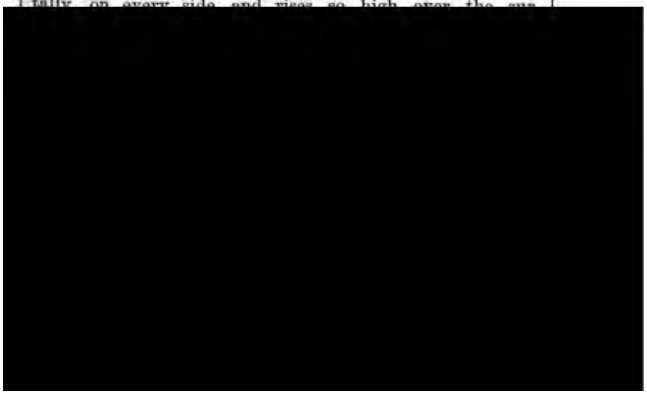
Mr MILLER began by remarking, that in lists of our Scottish fossils he found the names of only two species of Oolitic plants,—*Equisetum columnare*, and *Pinites Eggensis*. It is, however, not the palæontology of the country that is in fault, he added, but its geologists. The Oolitic deposits of Scotland do their part in furnishing the specimens; and if they are not known, it is only because the geologists have failed to examine and describe them. For many years past, however, he (Mr M.) had been gradually collecting in the Lias of Ross and Cromarty, and the Oolite of Sutherland, the vegetable species of the System, and he had at length accumulated materials enough to raise the list from two to more than fifty species,—not a very great number, regarded as the sole representatives of a Flora, but comparatively not a very small one, if we consider that up to 1837, when Dr Buckland published the second edition of his Bridgewater Treatise, Adolphe Brongniart had enumerated only seventy species of plants as occurring in all the Secondary formations of Europe, from the Chalk to the Trias inclusive. And, of course, these seventy species represented at least two Floras, —that of Brongniart's second, and that of his third period,— the New Red Sandstone and the Oolitic System. In justice, said Mr M., to the labours of one whose ear the acknowledgment could no longer reach, he had to state, that about twenty of the added species he had derived from the collection of a young man,—Mr George Hugh M'Kay,—a native of Sutherland, who died about three years ago. Mr M'Kay was a diligent and meritorious student, who, when spending his summer sessions at his father's house in Helmsdale, used to employ his leisure hours in collecting the fossils of the Lower Oolite, largely developed in that neighbourhood. He ultimately entered the navy, where he died; and his small collection had, since his death, come into Mr M.'s possession. Trees of the cone-bearing family seem to have been very abundant in Scotland, continued Mr M., during the Oolitic ages. They greatly abound among the shales of the Lower Oolite of Helmsdale. In examining, in that neighbourhood, a heap of materials collected along the sea-shore for burning into lime, he found that more than three-fourths of the whole consisted of fragments of coniferous woods, washed out of the shale beds by the surf; and the remainder of a massive coral of the Oolite,—*Isastrea oblonga*. Similar fossil woods also occur at Port Gower, at Kintradwell, at Shandwick, at Eathie, occasionally at Blackpots near Banff, and in the *island of Eigg*. As shown by their internal structure, they

consist of three species,—the already enumerated species *Pinites Eggensis*, and two other species identical, apparently with Scarborough conifers of the Oolite,—the *Peuce Hutchinsiana* and *Peuce Lindleiana* of Witham. Mr M. then went on to describe at considerable length the structural peculiarities by which these several species of woods are distinguished, and referred to certain general characteristics which they exhibit, indicative of the nature of the soil in which they grew, and of the seasons, milder or more severe, which had passed over them. Mr M. stated that he had seen trees of *Peuce Lindleiana* in the neighbourhood of Helmsdale, that exhibited in their cross sections more than a hundred annual rings circling round the pith. He had found in the Lias of Eathie three different species of pine or Araucarian cones,—one an oblong cone of considerable size, formed somewhat in the proportions of the cones of the spruce family; one a small cone somewhat resembling that of the Scotch fir; and one of intermediate size, and of a rounded form, like the cones of the cedars. In the latter he occasionally detected the thin oblong seeds of the plant as entire as in the cones of our recent pines. He had sometimes found, in the same Liasic beds, though rarely, very minute cones resembling those of the larch. The occurrence of cones associated with the coniferous woods of the Oolitic system,—woods which, though of extinct species, were decidedly of existing genera,—seems worthy, said Mr M., of special remark, in connection with the further fact, that with the coniferæ of the Carboniferous deposits we have not yet found in all our British coal-fields, with but a solitary exception, a single cone, save of Lepidodendra. Is it not possible that in the Carboniferous genera,—*Pinites*, *Pitus*, and *Anabathra*,—which approach but remotely to aught that now exists, the place of the ligneous scaly cone may have been taken, as in the junipers and the yews, by a mere succulent cone or perishable berry? Mr M. then ex-



Zamia, not yet figured or described, occur among the Liasic beds of Eathie, and with these the cones of at least two species of plants of the same genus, or at least family,—both of them curiously organized, and differing apparently from aught of the same kind that now exists. One of the two seemed to be of a character intermediate between the leathern, seed-bearing flower of *Cycas revoluta*, and the regularly formed cone of *Zamia pungens*. Mr M. exhibited specimens of at least five other species of Cyadites, including *Zamia lanceolata*, *Ctenis falcata*, and three other smaller species allied to *Pterophyllum*. With these there occurred specimens of a *Tæniopteris*, identical, apparently, with a species of the Virginia Oolite *T. magnifolia*. The fronds of some of the smaller Cycadites, said Mr M., could with difficulty be distinguished from those of ferns, which, both in their vernation and their general form, they greatly resembled. The true ferns of the Scottish Oolite were, he added, comparatively numerous. He had found in the Eathie beds, specimens of *Cyclopteris trichomanoides*, *Pecopteris Whitbiensis*, a *Pachypteris* akin to *P. lanceolata*, and a large-leaved undescribed *Neuropteris*. The Helmsdale and Kintradwell beds were considerably more rich. With *Pecopteris Whitbiensis*, *Pachypteris*, and the undescribed *Neuropteris*, they contained another and yet larger-leaved *Neuropteris*, also undescribed, with *Neuropteris recentior*. *N. arguta*, *N. linneafolia* *Sphenopteris arguta*, with two species of undescribed *Sphenopteris*, besides an undescribed *Phlebopteris*, and *Pecopteris insignis*, *Pecopteris obtusifolia*, and several other species too obscure in their venation to admit of classification. *Equisetum columnare*,—a gigantic horsetail of the Oolite from two to four inches in diameter, and which must have possessed originally a wide geographical range, for its remains occur at Baldissero in Piedmont, and at Blackheath in Virginia, as also on the Yorkshire coast, had been first detected in Sutherlandshire at Brora many years ago by Sir Roderick Murchison, and formed one of the two enumerated Scottish species to which, in the opening of his paper, Mr M. had referred. It was accompanied in the shale beds, associated with the Brora coal, by another Virginian and Continental species,—one of perhaps the last of the calamites, if a true calamite it was,—*Calamitis arenaceus*. Among the miscellaneous plants of the Scotch Oolite, Mr M. enumerated *Solenites furcata*, which occurs at Kintradwell; a *Clathraria* occasionally found in a quarry near Brora; a curious nondescript seed-spike, somewhat like that of a shot garden cress; fragments of spathes; fragments of what seem, from the venation, to be dicotyledonous leaves; an undescribed plant furnished with thick lanceolate, irregularly-alternate leaves, linearly veined; and a hirsute, brush-like termination of some nondescript think-stemmed plant, that presents from two to three club-like lobes enveloped i long hair. Mr M. then went on to describe the coal f the Oolitic system, both as it occurs at Brora, and in thin seam near Shandwick, in Ross. It rests, in the latter locality, over a dark bituminous shale, charged with lacus-

trine and brackish-water shells, such as cyclas and perna, and is overlaid by an arenaceous marine deposit, charged with belemnites, ammonites, phloadomyæ, and plagiostoma. The seam had been formed apparently in a marsh occupied for ages by forests of aquatic plants, chiefly calamites and equisetacæ, and into which the sea occasionally, and after wide intervals, quietly found its way. And then, through some sudden depression of the land, the waves rushed violently in, charged with mud and sand, and bearing with them many a disparted valve and broken ammonite, and the deposit became permanently a marine one. The Brora coal had been wrought more extensively, said Mr M., than any other coal of the Oolite in the British islands. Not fewer than seventy thousand tons had been extracted from one of the pits between the years 1814 and 1826, when the workings were finally abandoned as unremunerative,—rather, however, from the inferiority of the coal in quality, than from any defect in quantity. It flared and crackled in the grate as one of the most inflammable of coals, and threw out a cheerful blaze with many a bright jet of gas; but then, an odour somewhat resembling that of a long-used tobacco-pipe used to fill the apartments in which it was burnt, and the fire which it formed, though strong, was evanescent, and soon sank into a heap of gray ashes. Mr Miller concluded his paper, which was of considerable length, with some general remarks on the character of the Oolitic Flora. The Flora of New Zealand, he said, is remarkable for the great abundance of its ferns, and its vast forests of trees, which retain at all seasons their coverings of acicular spiky leaves. About two-thirds of the plants which cover the plains, or rise on the hill-sides of the country, are cryptogamic; and it is a curious circumstance, that so shallow is the soil, even where its greatest forests have sprung up, and so immediately does the rock lie below, that the central axes of the trees do not strike downwards into a tap, but a thick network of roots spreads out horizontally on every side and rises so high over the sur-



what remains, very considerable space in its vegetation; and with these there were associated, also in great abundance, the dominant families of the Pteroides,—Equisets and Lycopodia,—plants which, in almost every modern treatise on ferns, take their place as the fern-allies, or even as subordinate groupes of the fern family. To the true ferns, the greatly higher family of the Cycadaceæ, even in its modern examples, is recognised as bearing direct analogies;—both have their circinate vernation, and considerably resemble each other in the character of their leaves; and so much more nearly did their leaves approximate in the times of the Oolite, that some of our first fossil botanists have confessed themselves unable to determine whether certain Oolitic fronds, found in a good state of keeping, belonged to true ferns or to true Cycadaceæ; or whether, as is more probable, the families were not united in those early ages by some intermediate family, of which we no longer possess other than distant representatives. To the Cycas family that of the Coniferæ is so nearly allied, that we now find them classed under one head, in all our modern treatises, as the Gymnospermæ. Some of the lower plants of the Oolitic period, too, bore a marked resemblance to its coniferæ. The circumstance that in examining the foliage of some of its vegetable species, it is scarce possible to determine whether it had belonged to club-mosses or cone-bearing trees, Mr M. had already remarked; and the points of resemblance borne by the latter to the huge horse-tails of the period seem to have been not less striking. Mr Francis does not hesitate to say, in his work on British Ferns, that "the relations of the equisetaceæ to the coniferæ are so strong, both in external and internal structure, that it was not without some hesitation he placed the former among the fern allies." Mr Miller then represented the relationships of the Oolitic Flora by a pentagonal diagram, of which the sides represented in succession the *Coniferæ*, the *Cycadaceæ*, the *true Ferns*, the *Lycopodiaceæ*, and the *Equisetaceæ*, and ran briefly over the various points of resemblance which in that order served to connect each to each, and to form the whole into one. And such, continued Mr M., so far as is yet known, was the essentially poor but curiously related Flora of the Oolite,—a Flora which, in deposits more than four thousand miles asunder, is found to present the same general characters, and even the same species of plants, and which seems to have mainly differed from that of the Coal Measures in the introduction to so large an extent among its forms of the Cycadaceous family,—in the disappearance of many of the more anomalous types of the earlier system, such as Sigillaria, Ulodendron, Bothrodendron, and Favularia,—and in the nearer resemblance borne by all its families to vegetable types which still continue to exist. Further, there is a striking difference in the internal structure of the woods of the two periods, said Mr M., indicative apparently of a marked dissimilarity in the climatal conditions under which they had respectively grown. In the Carboniferous woods the annual rings are almost always either wholly obsolete, as in Pinites Withami and *Pitus antiqua*, or about as indistinct (as in Pinites medullaris), as we now find them in those intertropical trees of the present day, in which faintly marked concentric rings

indicate rather seasons of heat or drought than seasons of cold. In the woods of the Oolite, on the contrary, we see winter setting its seal not less decidedly in concentric lines of thickened tissue, than in the trees of our Scotch forests of the passing age; and we find these annual rings giving evidence, by their varying breadth and irregular grouping, that of the Oolitic summers, some, as now, were less, and some more genial, and that of the Oolitic winters, some were less, and some more temperate or severe. In the northern portion of our own country, this Flora of the Oolite sprang up over a subsoil composed almost exclusively of an Old Red Sandstone, which existed then, as now, as a solid, fossil-bearing rock; from fragments still locked fast among the interstices of the petrified stumps, and which seem to have been detached from the underlying mass as the trees fell, we determine that the bottom over which they grew was formed of the Lower Old Red flag-stones, charged with bituminized ichthyolites; and the vegetable mould derived from this rock, —save that, from a lack of the boulder clays, it must have been poorer and shallower than that which overlies our Old Red deposits in the Lowlands,—must have somewhat resembled the soil of the lower plains of Caithness, Cromarty, and Easter Ross. And on this Palæozoic platform, long exposed, as the Oolitic conglomerates testify, to denuding and disintegrating agencies,—a platform beaten, where it descended to the sea-level by the surf, and washed in the interior by rivers, with here a tall hill or abrupt precipice, and there a flat plain or sluggish morass,—there grew vast forests of cone-bearing trees,—tangled thickets of gigantic equisetaceæ,—numerous forms of Cycas and Zamia, —and wide-rolling seas of fern, amid whose open, insular spaces club-mosses of extinct tribes sent forth their long hirsute arms, spiky and dry, and thickly mottled with their pseudo-spore-bearing catkins.

vegetation of the Oolitic period had never been seen in Scotland before. There were among them some which seemed to be quite new. With reference to Mr Miller's pentagonal diagram, it was true that the great mass of the Oolitic Flora was composed of the five natural families indicated; but there were two specimens on the table which appeared to possess a dicotyledonous structure, and were therefore exceptional to the rule, and interesting from that very circumstance. Further researches would doubtless throw additional light upon the subject, and it was to be hoped that Mr Miller would take an opportunity of examining the Oolitic deposits in the Isle of Skye, referred to by the Duke of Argyll.

Professor BALFOUR warmly concurred in the eulogium bestowed upon Mr Miller's labours, remarking that scarcely anything had been previously known of the Oolitic Flora of Scotland. He adverted to the great difficulty of distinguishing between the foliage of the Lycopodaceæ, when in a fossil state, and that of coniferæ of the genera Thuya and Dacrydium; and made several interesting remarks on the absence in the Oolitic Flora of the more extraordinary Carboniferous forms, such as Sigillaria and Lepidodendra,—connecting links apparently between the Cryptogamic and Gymnospermous families. He deemed it highly probable that in even the Oolitic Flora there had existed links, now wholly wanting, between families such as the Ferns and the Cycadaceæ.

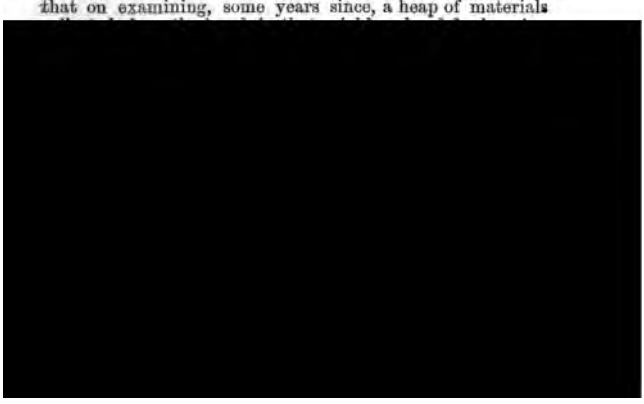
Mr MILLER stated in conclusion, that the fragments of leaves, resembling in their venation those of dicotyledonous plants, to which Dr Greville referred, are of exceedingly rare occurrence in the Oolitic beds of Sutherland, which differ materially in that respect from the Tertiary beds of Mull, discovered by his Grace the Duke of Argyle, in which the prevailing forms are dicotyledonous. His [Mr M.'s] pentagonal diagram could, of course, only be regarded as representative of the prevailing vegetable families of the Oolite and their relations, so far as its Flora was yet known; and it was submitted to the Society as merely provisional, along with the seeming exceptions. These last, however, were as rare in the long-explored Oolitic beds of England and America as in those of Scotland.

Royal Physical Society – 28 Apr 58.

II. On the Corals of the Oolitic system of Scotland, with a notice of certain lithodomous shells of the same period, by which some of the more massive species were hollowed in their recent state, by Mr Hugh Miller.

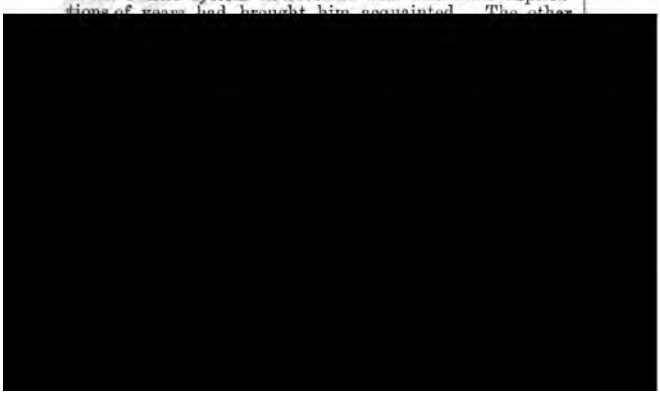
Mr MILLER began by remarking that corals are extremely rare in the Lias. Messrs Milne-Edwards and Haime figure, he said, in their elaborate "Monograph of the British Fossil Corals," only three Liasic species, two of them exceedingly minute, *Turbinolidæ*, and the third apparently a *Cyathophyllum*, of doubtful lineage, and very probably, it is stated, a misplaced Palæozoic specimen. In the Lias of the eastern coast of Scotland, at Eathie, Nigg, and Shandwick, Mr M. had not succeeded, after the search of years, in finding a single coral; in that of Skye, however, he had been more fortunate. When examining, nearly eight years ago, the Liasic deposit at Broadford,—by far the most extensive development of this formation in Scotland, for it runs across the island from sea to sea, in a belt from two to four miles in breadth,—he came, near the base of the formation, and at a little distance from where it leans against the so-called Old Red Sandstone of Slate, on what seemed to be a dark-coloured bed of concretionary limestone, of very irregular surface, and varying from three to four feet in thickness. The seeming concretionary masses were separated by what appeared to be a gray, indurated mud, which wrapped them round, concealing their true character; but where the edge of the bed was exposed to the lashings of the surf, the hardened mud had been washed away from the calcareous nuclei; and Mr M. was not a little surprised to find, that the seeming concretions were massive corals, apparently all of one species, and evidently of the family Astreidæ. The masses in this unique bed, each a coralluin, are of irregular form, but usually flat and oblong, and vary in size from nine or ten inches in length by six or eight in breadth, to from three to four inches in length by from two to three in breadth; while in thickness they vary from about two-and-a-half inches to less than an inch. They are thickly covered on all sides by shallow polygonal calices, irregular both in size and form, for they vary from nearly half an inch to little more than a line and a half in breadth, and present from four to six sides. The dividing walls are thin, and not prominent; and each calice is traversed by from thirty to sixty septa of unequal size. A coral of the Inferior Oolite, *Isastrea tenuistriata*, resembles this Isastrea of the Lias more closely than any other fossil species yet figured; but in the Oolitic Isastrea the calices seem to be more equal in size, and more regular in form; and from the smallness and fragmentary character of the specimen given in the monograph, Mr M. was unable to determine, he said, whether it possessed what seemed to be the most marked characteristic of the Skye coral. In all the other species of Isastrea Mr M. had yet seen, each corallum has a determinate base from which the coralites radiate; whereas in the Liassic species they seem congre-

gated together on all sides of the corallum (which appears to have had no base), like the cells in a honeycomb, and even cover wen-like protuberances on the general surface, in a way that precludes the possibility of their having radiated from any common axis or centre. The history of this coral bed of Skye, so unique in the Lias, seems to be simply as follows :—In what is now the Inner Hebrides, as in other parts of the British islands, the Liasic deposit appears to have been a muddy one, und unfavourable, in consequence, to the growth of corals. Comparatively early in the period, however, a pause took place in the process of deposition,—massive corals began to form at the bottom of a clear sea; the term of rest was protracted for ages; as one corallum died another formed over it, until at length the bed had become several feet thick, and then the deposit suddenly returned to its old conditions. An arenaceous mud began to be cast down, which insinuated itself into all the interstices of the bed, as the run lime of the mediæval builders insinuated itself among the loose stones with which they filled up the interior portions of their walls; in circumstances so ungenial the coralites died; stratum after stratum,—not a few of these richly charged with the peculiar shells of the Lias,—ammonites, belemnites, and the characteristic gryphæa incurva, were heaped over them to the depth of several hundred feet; in a few of the overlying strata the same coral again appeared, but only in small and unfrequent specimens; and, so far as we yet know, not until the times of the Lower Oolite did corals in any considerate abundance again live in the seas of the Scottish Oolitic System. The Lower Oolite, as developed in the neighbourhood of Helmsdale, on the north-eastern coast of the kingdom, is comparatively rich in corals; at least, if species be not numerous, individual specimens are far from rare. Mr M. had stated to the Society, on a previous occasion, that on examining, some years since, a heap of materials



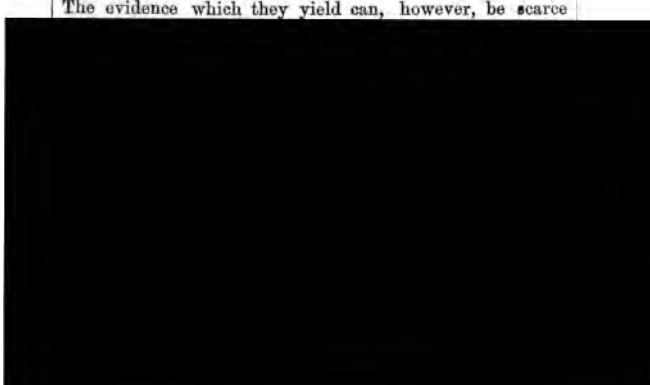
the centre of the visceral cavity. In the thickness of its walls and the character of its septa, this Helmsdale Isastrea greatly resembles the *Isastrea oblonga* of the superior Oolite, a species which has been found hitherto only at Tilsbury, Wiltshire. It also resembles, however, though in a less degree, *Isastrea Richardsoni*, a coral of the Lower Oolite; but is possibly a new species. Mr M. had found in the same beds, though much more rarely, what seemed to be a different species of Isastrea, though closely allied to the one described. The corallum, massive like that of the other, is always greatly smaller; the calices, however, are considerably larger, and rather thinner in the walls, which do not stand up so abruptly over the central hollows; the septa vary from about twenty to twenty-four in number; and where they meet in the centre, they rise in many of the calices into a protuberant knob like the termination of a true columella, which, however, like all the other species of the extinct genus Isastrea, it wants. A Thamnastrea is also found in the same beds, but always hitherto in a state of bad keeping. Unlike any of the Oolitic Thamnastrea figured by Messrs Milne-Edwards, and Haime, the corallum forms a mere incrustation on rocks and stones of older deposits than the Oolite, and is in some specimens less than half a line in thickness: the calices are small and shallow, and rather thickly set. The circular elevation, which corresponds in this genus to the enclosing wall of Isastrea, is very apparent in weathered specimens, but, as in *Thamnastrea Lyelli*, only faintly visible in those that are less worn; while, as in the species *Thamnastrea scita*, the columella, if it at all possessed one, was rudimentary. Mr M. had usually found this species encrusting masses of indurated Old Red Sandstone of the flagstone formation, which must have been as ancient a looking rock in the times of the Oolite as it is now; and, when laid open by the waves along the beach, must have exhibited its ichthyolitic remains in their present state of keeping. In fine, in its rocks and stones, this beach of the Oolite, on what is now the eastern coast of Sutherland, must have resembled that of the neighbouring county of Caithness in the present day. And as on the latter shore, as we approach the line of extreme ebb, we find rolled masses of dark gray flagstone, partially covered with pale-colored nulliporite encrustations, there would have been found, had there been an enquiring eye to prosecute the search, angular dark gray masses, bearing their encrustations of Thamnastrea, along the old shores of the Golite. But while the framework of the scenery must have been thus the same in both eras, and the same incalculably ancient sea must have broken in both against the same old fossil-bearing rocks, how entirely different must not the vital scenery of the two periods have been! Where we now see microscopic lepralia and dwarfish sertularia, huge Isastrea, embroidered by their flower-like polypes, and wide-spreading sheets of Thamnastrea, similarly mottled, must have

gleamed white through the green depths of the water; as their existing representatives may be seen gleaming from the quiet recesses of tropical lagoons in the present day; the ammonite and belemnite must have careered over and around them amid the sheen of ganoidal scales; and where the seal now disports, the plesiosaurus must have gambolled, and the goggle-eyed ichthyosaurus have darted along the tracts now traversed by the porpoise and the whale. The Oolitic deposits in the neighbourhood of Helmsdale consist mainly of beds of a laminated, dark-coloured, arenaceous shale (charged with ammonites and belemnites, serpula and terebratula), which alternate with beds of a rough conglomerate, formed chiefly, as had been already intimated, of Old Red Sandstone materials. The corals,—especially those of the genus Isastrea,—occur both in the shales and the conglomerates; but it is amid the rocky masses of which the latter are composed that they seem to have grown; and in the shale we not unfrequently find them overturned, as if they had been torn with violence from their proper habitats on some stony ridge or hard bottom, and buried head-downwards in the mud. Corals, apparently of two different species, occur at Brora, but in so defective a state of keeping, that little else can be said regarding them than that they seem to belong to the genus Thecosmilia. In both the corallum is composite and dendroid; but in the one the branches strike off at more acute angles than in the other. Its calices, too, are more rounded at their edges, and its septa less simple, more flexuous, and more prominently denticulated. So imperfect is their state of preservation, that neither species exhibits the exterior coating or epitheca characteristic of the genus. The place in the system in which they occur is higher than that of the beds at Helmsdale, but not higher than the base of the Great Oolite. And such, said Mr M., were all the corals of the Oolitic system in Scotland with which the explora-



so many of the calcareous masses that lay scattered on the beach on every side of the specimen; but it is shut firmly up by the coarse gritty sandstone in which the coral itself had lain buried; and a fragment of carbonized wood lies embedded in the entrance. The cave is curtained across by a wall of masonry, immensely more ancient than that which converted into a prison the cave of the Seven Sleepers." Several years, however, elapsed from this time, ere Mr M. succeeded in detecting the shells by which the cavities had been formed; and not until two years ago did he find specimens sufficiently entire to admit, and that still but imperfectly, of description. They seem to have been slim wedge-shaped bivalves, greatly resembling modiola, but belonging evidently to the genus Lithodomus. Sir Roderick Murchison, in his great work on the Geology of Russia, figures a Lithodomus of the Oolite of that country, under the specific name *Lithodomus Eramanus*; but it is a greatly smaller shell than the Scotch one, measuring little more than a quarter of an inch in length; whereas the Helmsdale species measures, in Mr M.'s larger specimens, two inches and a line in length. The Russian species, however, in proportion to its general size, seems to have been a massier and broader shell. An Oolitic bivalve figured in the same work as *Mytilus vicinalis*, very much resembles, both in size and form, save that it also is proportionally a massier shell, one of his smaller specimens. Some of the larger masses of the Helmsdale Isastrea are much fretted by this busy excavator. In one of the smaller fragments of coral on the table we find the fossil remains of three individual shells that had burrowed in it, and the cell of a fourth; and in the massive corallum beside it there are no fewer than four-and-twenty of these excavations now filled with grit, but doubtless once tenanted by a borer a-piece. If, as is probable, it was living at the time when the excavators were at work within it, and possessed, what is more questionable, the sense of feeling, it must have been wofully subject to stomach complaints and fits of griping in the bowels. Though these lithophagi of the Oolite occur chiefly in the corals of the period, they are not exclusively restricted to them. Mr M. had found them, though rarely, in Old Red flagstones of the conglomerate, and had ascertained, that had there been naturalists in those days to differ and dispute, the question might as certainly be raised as now, whether the stone-boring shells made their way into the masses which they inhabited by mechanical means, or through the agency of some acidulous solvent. The corals, in their recent state, were of course calcareous, and, in consequence, dissolvable by an acid; and the flagstones which the borers usually selected also contain a good deal of calcareous earth; but their prevailing material is so largely aluminous and quartzose, that it seems scarce likely that a mere solvent could have perforated them. Mr M. ventured, in conclusion, he said, two general remarks. First, the corals of the Oolitic system in Scotland, massive in size, and occurring in

some localities in very considerable abundance, resemble in these respects no recent corals of the higher latitudes. The corals of the higher latitudes are, we find, either diminutive or few. *Groupes* of large corals are characteristic of the intertropical seas, or at least of seas of either hemisphere that border on the tropics. Mr M. had seen an Isastrea of Helmsdale that measured about two feet and a-half in length by about eighteen inches in breadth, and which, as he had said, a strong man could scarce raise from the ground; and arborescent masses of *Thecosmila annularis* have been found in the Coral Rag of England, that measured from a foot and a-half to two feet in height. There occur no such corals now in seas which lie between the fiftieth and sixtieth degrees of latitude, whether to the south or north of the equator. And though he (Mr M.) would not found much on one or two exceptional species, he did think that, seeing we would at once pronounce a similar group of recent corals to be the product of seas greatly warmer than our own, we might, he thought, be permitted to infer,—reasoning from what we know,—that the Oolitic seas of what is now Scotland were of a higher temperature than our Scottish seas of the present day;—and that, in short, in the corals of the Scotch Oolite, we have one of many evidences that in this early period these northern regions enjoyed a greatly more genial climate than they do now. Mr M. added, however, that in the same beds, mingled with fronds of cycas and zamia, and the stems of gigantic horsetails,—all now the productions of a warm climate, and that seem to give evidence to the same fact as the corals,—there occur numerous fragments, and occasionally whole trunks, of fossil pines, that apparently testify, by their annual rings of small size, indicative of slow growth, to a climate as ungenial and severe as that of Sweden or Norway. The evidence which they yield can, however, be scarce



the geologic creations. So far as we know, animal life existed at all times, when it existed at all, in its four master types, and no more; and these in the Oolitic ages—life radiating round a centre, as in the Isastrea—life lodged within a series of rings, as in the annelids and the crustacea—life combined with a duality of corresponding parts, as in the cuttle fishes and the clams,—and life associated with a brain and vertebral column, as in fishes and reptiles—were not less prominently developed than now. Had a Cuvier then existed to write the history of animated nature, the various classes would have occupied very different proportional spaces in his "Animal Kingdom" from that occupied by those of the present time; but the master divisions—vertebrata, mollusca, articulata, and radiata—would have been the same. For of all the creations, repeated Mr M., in the leading ideas there has been no change. Two of these we find exemplified before us (he continued) in single specimens;—those in which the lithodomi lie sepultured in cavities hollowed in Isastrea; and we are enabled to trace this identity of idea into yet minuter ramifications, when we thus find that along these old Oolitic shores of Scotland, as along the shores of our country in the present day, the rocks were inhabited by their hermit shells,—the *Edomites* of the molluscous world, as a modern naturalist poetically terms them,—that spent silent lives in excavating for themselves cells in the stone, in which they watched in patience for the food brought them by wavelet and current, and which, like the cells of so many other anchorites and recluses, were ultimately to prove their sepulchres. The idea that stones and rocks should be thus inhabited is an idea old as eternity; it must have had being *as an idea* ere the existence of rock, or coral, or molluscous life; for He from whom it emanated saw the end from the beginning, and makes no accessions to His fund of thought; and to be permitted thus to trace it towards its source, and to detect it embodied in a creation whose last surviving organism perished myriads of ages ago, enables us in some degree to conceive of the fact, and to conceive also of the fixed character, of that Master Existence, the Author of all, who said, in a long posterior age, when revealing Himself to man, "I am the Lord, I change not."

ON THE ANCIENT GRAUWACKE ROCKS OF SCOTLAND.

By Hugh Miller.

Read before the Royal Physical Society, 13th Nov. 1852.

PART FIRST (HISTORICAL.)

"From Portpatrick on the west coast, to St Abb's Head on the east," says Dr James Hutton, in his far-famed Theory of the Earth, "there is a tract of Schistus Mountains, in which the strata are generally much inclined or approaching to the vertical situation; and in these inclined strata," he adds, "geologists allege there is not to be found any vestige of organized body." But the opinion can be "proved," he further states, "to be erroneous." He himself, indeed, though he had been occasionally employed in examining the rocks of this "south Alpine country of Scotland" for more than forty years, had failed to find in them any traces of the organic; but his distinguished friend Sir James Hall, when travelling, in the summer of 1792, between Noblehouse and Crook, had detected sea-shells in "an Alpine limestone" by the wayside, at Wrae Hill, in the parish of Broughton, and thus demonstrated, as the limestone is intercalated with the Schistus rocks, the fossiliferous character of the deposit. Even geologists had not yet become palæontological; and we find Sir James, in a passage quoted in the "Theory," describing the shells which he had detected, simply as "forms of cockles." He was greatly more exact, however, in his appreciation of the mechanical peculiarities of the deposit; and in his description of those strange convolutions of the strata which give to the south of Scotland its series of axial lines, and its repetitions of beds and bands that come ever and anon to the surface, and continue to render the place, of at least its nether groupes of rock, so obscure, is still approvingly referred to by our higher geologists. To account for these strange foldings, Sir James, in his paper in the Transactions of the Royal Society of Edinburgh, "On the vertical position and convolutions of certain strata, and their relations with granite," broached that theory of lateral pressure, applied by some unknown force outside the area of the foldings themselves, which is still regarded as the best yet originated on the subject, and illustrated it by his famous *experiments* of the bands of variously-tinted clays and *the layers of differently*-coloured cloths, which he succeeded *in pressing, by the* application of lateral force, from a horizontal *into* a convoluted position. His paper did not appear

in its completed form until the year 1812; but as his theory had been originated more than twenty years previous, when, on visiting, in the company of Dr Hutton and Professor Playfair, a portion of the east coast of Berwickshire, he found no fewer than "sixteen distinct bendings of the strata in the course of about six miles," and as, long ere the publication of his views and experiments, they were well known to his scientific friends, I refer to them at this early stage in my brief sketch of the history of geological discovery in our Scottish Grauwacke.

Dr Hutton had described the "Alpine Schistus" of the south of Scotland as belonging to the Primary class of rocks, and founded an argument for his theory on the fact that, in direct opposition to the belief of geologists regarding the deposits of this special division, they yet do contain fossils. In 1805 Professor Jameson published his "Mineralogical Description of Dumfriesshire;" and to him must be assigned the merit of first determining that these ancient schists belong, not to the Primary, but to what Werner has termed the Transition or Grauwacke Series. He states in this work, that he had traced these Transition rocks in Scotland "from the northern extremity of the Pentland Hills, which is about six miles distant from the shores of the Frith of Forth, to Lang-robie, in Dumfriesshire, about three miles from the Solway Frith." We find him, too, giving very correctly the other limits of the system as developed in our southern counties, and classifying with much precision the mechanical and mineralogical peculiarities of the rocks which compose it. But when he comes to speak of its organisms, he is content to discuss the sub-

not possibly have avoided making the observation. He has been very properly punished for the omission. The assertion that Grauwacke contains petrifactions has been denied, and our author has been challenged to produce a *single* petrifaction in the Grauwacke of Dumfriesshire. To us, who know perfectly well that vegetable petrifactions are very common in that Grauwacke, this challenge appears not a little bold." Thus far the reviewer. He seems to have observed for himself, but not very correctly. Mr Harkness tells us, in a paper which appeared in the *Geological Journal* for 1851, that though the Dumfries Grauwackes contain their thick bands of Anthracite, of apparently vegetable origin, there has been detected in them no vegetable remains whatever; they abound, however, in graptolites; and it was probably these leaf-like zoophytes, whose nature is still so imperfectly understood, that caught the eye of the reviewer, and constituted his "vegetable petrifactions." The Grauwacke of Scotland does, however, contain vegetable impressions apparently fucoidal; though they are far from common in any of the rocks which I have yet seen, and yield no characters by which they can be distinguished from the simpler fucoids of the Old Red Sandstone. In one of the specimens now on the Society's table, derived from the shales of Girvan, there occurs a fucoidal stem of this latter description, associated with graptolites of the double-sided genus *diprion*,—a genus never found, it is said, save in the Lower Silurian.

In 1808, Professor Jameson published that third volume of his "System of Mineralogy," in which he fully developed his geological views, and described, in language that has since become obsolete, the character and order of succession of the various formations. The work, however, added nothing to the previous knowledge of our Scotch Grauwacke, save, perhaps, a very curious hypothesis regarding its convoluted strata, framed evidently to meet the theories of Hutton and Sir James Hall. "Very striking curvatures sometimes occur," said the Professor, "in Transition or Grauwacke slate. The waved and concentric circular appearances *are the effects of crystallization*, whereas other curved and angular appearances seem to be connected with the mode of deposition of the strata, and may be traced either to inequalities of the fundamental rock, or to irregularities in the deposition of the strata themselves." We do not now expect so much from crystallization; nor, when we see fossils spread out on a vertical plane, do we *try to* believe that, in defiance of the law of gravitation, *they had* pasted themselves there of old, as one pastes

prints upon a screen; but as a fossil theory may be in some instances scarce less curious than a fossil plant or animal, the use of the extract will, I trust, be forgiven me. About four years after the publication of Professor Jameson's work, the late Mr Thomas Allan of this city read a very able paper before the Edinburgh Royal Society, on the "Transition Rocks of Werner," in which we find reference made to their fossiliferous character in our southern Highlands. But there are no new localities given. Over the one discovery of Sir James Hall at Wrae Hill our Scotch geologists seem to have hybernated for more than forty years. In truth, the great controversy which then divided them into Plutonists and Neptunians, seems to have operated unfavourably on the progress of general discovery. In looking over our bookshelves for some wanted volume, we soon come to find that we have eyes for only it, and that all the other volumes fail to attract notice or attention. And such seems to have been the case with not a few of our Scotch geologists;—they went out to search among the shelves of that great geologic library, in which the early histories of the globe are stored up, for whatever could be made to tell in favour of their own hypothesis, or to militate against that of their neighbours; and, engrossed by this one object, they seem to have been indifferently suited for the accomplishment of any other. In the various notices of our Scotch Grauwacke which occur in the Transactions of the Edinburgh scientific societies during the years in which the battle raged between the two schools, I do not

equally remarkable for the boldness of its theories and the truthfulness of its observation,—geologists were first told that there exist fossils in the Grauwacke-slate of the Pentlands. The organisms of the older rocks are not unfrequently restricted to a single stratum: even in the Lower Old Red Sandstone one may pass along sections of the strata many hundred feet in thickness, without detecting a trace of aught organic, and then find in some thin layer, perhaps not a foot in thickness, the fucoids, or fishes, or minute bivalves, of the formation, congregated by hundreds and thousands; and in the Scotch Grauwacke this peculiar arrangement obtains in a still more marked degree. The organisms of a wide district of country are confined often to a single layer, occupying scarce half an inch, in a section thousands of feet in vertical extent. And such seems to be the arrangement among the ancient slates of the Pentlands. Mr Maclaren found his fossils near Deerhope-foot, at the side of a small stream that falls into the North Esk; and he describes them in the portion of his work devoted to the geology of the Pentland range, as of two kinds. In one, fragments of what seem minute trilobites are congregated together in thin layers; in the other there are the distinctly marked impressions of what appear to be orthoceratites. I owe two of those Pentland fossils to the kindness of Mr Maclaren. The one, apparently a portion of an orthoceratite, exhibits a side view of what seem to be five of the septa; the other greatly resembles that curious and still but imperfectly understood vegetable of the Coal Measures, *Sternbergia approximata*; but it is in all probability not a vegetable, but an animal organism,—very possibly an orthoceratite also. One of these specimens bears on the label the date of its discovery, (7th April 1834),—a date five years anterior to that of the publication of Mr Maclaren's volume, and forty-two years posterior to the discovery of Sir James Hall. The fact that by much the greater part of half a century should have intervened between the first and second discoveries of organic remains in our Grauwackes,—for, waiving the claim of Mr Laidlaw, whose discovery seems never to have been recorded, and can now be associated with neither locality nor date, Mr Maclaren's *is* decidedly the second,—is a fact of itself sufficient to show that our Scotch schools were in those days not zealously palæontological; and we know from other sources, that arguments were sought after within their precincts, with much more avidity than fossils. *But the error* has been seen, and in part corrected; and the *future of* Scotch Geology bids fair to be characterized by

the doing of more and the saying of less.

In the same year in which Mr Maclaren published his "Geology of Fife and the Lothians," the "Silurian System" of Sir Roderick Murchison appeared,—one of those great works which form eras in the history of science, and from which, as from the charts of some distinguished voyager, after-explorers have learned to shape their course aright, and to recognise as familiar and easily definable, tracts previously unnamed and unknown. In both the old world and the new, the great divisions first laid down in this work by Sir Roderick have been detected and identified, and an introductory book added to the organic history of our planet, from the rich and varied materials which they supply. For, however, several years after its publication, our Scottish Grauwacke continued to remain a *terra incognita*, as before; for though there appeared from time to time truthful descriptions of the deposit itself, its place in the scale was still doubtful. Two years after (1841), Mr James Nicol,—now Professor of Geology in Queen's College, Cork,—produced his Prize Essay on the Geology of Peeblesshire; and to an accurate description of the mineralogical components of the Grauwacke of that county, added a new locality for its fossils in Grierston, near Traquair, where, in a slate quarry, there occurs thin but continuous layers of graptolites, often in a state of the most exquisite keeping. Some of the finest Scottish specimens of this ancient organism which I have yet seen I have derived from this Grierston deposit. We also find Mr Nicol referring, in his Essay, to that limestone quarry of Wrae Hill, in

"Geology of Scotland." And in referring, in a general notice, to our Grauwacke deposits, we find him stating, that the "formation" to which they belong "corresponds to some of the beds of the Cambrian system, as existing in Wales;" and that in graptolites discovered in the Grauwacke slates of Innerleithen, "the first indications of organized fossils appear." He adds, that "distinct specimens of these lay before him as he wrote, which had been presented to him by the discoverer, Mr James Nicol." In 1845, Mr Nicol published his Guide to the Geology of Scotland,—a work which I have ever since carried about with me in my geologic rambles, and which, in every instance in which its author has described from his own observations, I have found correct. In this useful work, we find him again referring to the graptolites of Grierston and the shells of Wrae Hill; and, further, briefly intimating yet another Grauwacke locality rich in fossils, though he was evidently in doubt regarding its true place in the scale. "In a limestone below the coal near Girvan," he remarks, "Silurian fossils are said to occur,"—a circumstance, not unfrequent," it is added, "in the Mountain Limestone of Scotland." No one, however, is now more thoroughly convinced than Professor Nicol, that the Silurian organisms of Girvan are not organisms of the Carboniferous series; that, on the contrary, they definitively determine the place and age of the deposits in which they occur as Lower Silurian; and further, that they throw more light on the history of this ancient system, in its development in the southern Highlands, than the fossils of all our other Scottish localities put together.

In January 1848, Mr Nicol, at that time Assistant Secretary of the London Geological Society, read before that body a paper on the Silurian rocks of the valley of the Tweed, which was afterwards published in the Journal of the Society. Even at a period so recent he could properly state, in his introduction, "that there is perhaps no extensive formation in the British islands of which we possess less certain geological knowledge than of the rocks constituting the great mountain chain which crosses the southern counties of Scotland from east to west." His paper, however, served to add considerably to the little previously known regarding the deposit. Among the fossils by which it was illustrated Mr Salter recognised the fragments of five several genera of trilobites, and an equal number of genera of shells, chiefly brachiopods, all of a character indicative of the Lower Silurian group. About the same time a collection made from the Grauwacke of the shores of Kirkcudbright was submitted to the London Geological Society by Lord Selkirk, and was found to be of an Upper Silurian

character; indeed,—as appeared from the identity of some of the fossils,—of the age of the Wenlock shale. In the May of the same year in which Professor Nicol submitted his paper to the public, the subject was still farther elucidated in a valuable memoir by Mr Carrick Moore, secretary to the Geological Society, "On the Silurian Rocks of Ayr and Wigtonshire," which added yet farther to our knowledge of the fossils of these ancient rocks, and in which, in its published form, the first Scottish Maclurea was figured and described, though somewhat doubtfully, from the imperfect state of keeping of the specimen, and under another name. At the meeting of the British Association, held in this city in 1850, Professor Sedgwick read a paper on the "Geological Structure and Relations of the Frontier Chain of Scotland," which derived a peculiar value from the previous labours of that great geologist in the older Silurian rocks of England, and in which he divided our Grauwackes, though with much hesitation, especially with respect to both the earlier and later beds, into five great divisions,—four of them belonging to the Lower, and the fifth *probably*, as he stated, to the Upper Silurian. In comparing the Scottish with the Cumbrian chains, he remarked that the lowest and oldest fossils of both appear to be graptolites; and in a paper on the graptolites of the black schists of Dumfriesshire by Mr R. Harkness, which appeared in the *Geological Journal* of last year, we find a minute description, accompanied by good figures, of these earliest inhabitants of what is now Scotland.† They are judged to have been zoophites, akin in some of their

for some distance along one of the middle reaches of the Moray Frith, and at the steep edges of which the water deepens suddenly from about twelve to about thirty fathoms. The bottom on either side is gravelly and hard, whereas the ravine is charged with a dark adhesive mud, abounding in fish-bones, and which intimates to the sense of smell, when brought to the surface, that there must have entered into its composition no small portion of organized matter. Now, this muddy ravine abounds with sea-pens. When not a specimen can be procured on the hard ground on either side, the fisherman's lines, when his boat drifts across the hollow, become charged with them;—every muscle bait brings up attached to it what the fishers of the Frith term its "sea-tree," so that specimens may be procured by the hundred. And from the dark-coloured, finely-grained, semi-bituminous character of the slates in which the graptolites chiefly occur, it is apparent that they also loved a muddy habitat.

I have now to refer to but two other papers on our Scotch Grauwacke. In 1849, Professor Nicol made the Silurian deposits of the south-east of Scotland the subject of yet another very able memoir, in which he specified several new localities for its fossils, and added to the previous list at least one new fossil more,—a hitherto undescribed species of Graptolite. He bestowed much care, too, in ascertaining the general *direction* of the beds and mountain ranges of our southern Highlands; and found it coincident, in an average drawn from no fewer than sixty-six several observations, with the direction of the continuous band of clay slate which, running diagonally from sea to sea, reclines, at a steep angle on the northern side of the great Lowland valley of Scotland, against the flanks of the Grampians. And,—to conclude the purely historical portion of my subject,—in 1851 Sir Roderick Murchison contributed a paper on the "Silurian Rocks of the South of Scotland," accompanied with descriptions and figures of its characteristic fossils (especially those of the Girvan deposits) which gives us to know, on certainly the highest authority, that whilst the true place of those apparently older members of the Lower Silurian system in Scotland, which are represented by what are the first and second of Professor Sedgwick's five great divisions, is, as the Professor himself observes, exceedingly doubtful, there can be scarce any doubt entertained, that in the deposits of Girvan and Kirkcudbright we possess the analogues and *representatives* of the middle and upper members of *the Lower* Silurians of England, and the lowest mem-

See Murchison, 1835 p. 468 for notice of the existence [illegible] fossils) of the Silurian rock [illegible]

ber of its Upper Silurians. For many years we have been accustomed to regard our Scotch Grauwackes and Grauwacke-slates as remarkable for their paucity in organisms. Sir Roderick seems, on the contrary, to have been struck by their abundance, and the distinctness with which they tell the story and exhibit the character of the deposits which enclose them. "Fossils abound," says this first of geologists, in describing Mulloch Hill, in the neighbourhood of Girvan, "and for the most part their shells are so well preserved, that great was my astonishment when I cast my eye over the surfaces of this rock, and thought of the long time which had elapsed before such unequivocal and really beautiful Silurian types had been made known in Scotland." The perusal of Sir Roderick's paper greatly excited my curiosity. I had visited, nearly seven years before,—guided by the descriptions of his "Silurian System,"—the rich deposits of middle England,—the Wenlock limestones and shales of Dudley, and the Upper Ludlow and Armistry deposits of Sedgley and its neighbourhood; and I was now desirous to decipher, under his guidance, the characters of those added pages to the geologic history of our country, from which his paper had led me to expect so much. And, availing myself of a pause in my professional labours, towards the close of last May, when the two General Assemblies were sitting, and when all our abler clergy were speaking articles in the form of speeches, and so rendering it unnecessary that I should write any, I set out, in the middle of a tract of very delightful weather, for Girvan.** See note ** page 263 opposite

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"Silurian System" or "Russia" of Murchison, do I find any species figured that at all reminds me of this emphatically ancient Scottish shell. I may add, that the limestone in which it occurs is at once highly crystalline and strongly bituminous.

† There also appeared in the same number of the *Geological Journal* (that for February 1851), an interesting paper by Mr Harkness, 'On the Silurian Rocks of Dumfries and Kirkcudbrightshires," to which I have already incidentally referred, in noticing the fucoidal impressions of the Grauwacke.

** In 1834, Mr David Milne read before the British Association, which held that year in Edinburgh, a well-written paper on the geology of Berwickshire; which received in 1835, in an extended form, the prize of the Highland Society. It contains a graphic and interesting description of the Grauwacke rocks of the county of Berwick, to which I would have referred in my brief historical sketch, had it not been rather of a literary than scientific character. It is simply a popular digest of the views and descriptions of Sir James Hall; and reproduces, slightly modified, in the form of an illustration, his experiment of the variously-coloured cloths; but presents to the geologist no *fact* to which I could have adverted as a fact unknown before. I extract the following passage, both for its general interest, and as forming a not unfavourable specimen of the paper in which it occurs:—

"But whilst, generally speaking, the Grauwacke strata of Berwickshire run east and west, and are nearly vertical, in some places they *fold over one another* in every imaginable manner. The bold cliffs between Burnmouth and Eyemouth, and the still loftier precipices at St Abb's Head, present the most interesting and perplexing sections of these twistings and foldings. They are, generally speaking, found most abundant and most fantastic among the strata which have a slaty structure. Pile a number of carpets over one another horizontally, and then elevate the whole mass, by pushing the two opposite sides towards each other,—the central parts will fall and fold over, and, if cut across, would present a multitude of convolutions and twistings. This homely illustration not unaptly represents the stratification of the Grauwacke rocks at St Abb's Head, at Dodd's Mill, at Eyemouth, and on the Tweed near the Flybridge; but the comparison fails in one respect, when we reflect on the immense weight and small tenacity of solid strata of rock, in consequence of which the contortions, fractures, and dislocations, become a thousand times more frequent and complex.

"That these strata could not always have been in the extraordinary attitudes and positions in which we now behold them, it requires little reflection to be convinced of. For both experience and reasoning assure us, that all rocks which are stratified, and of sedimentary origin, as the Grauwacke rocks undoubtedly are, have been originally in regular and parallel layers, at the bottom of a sea in which they were deposited. The mind, when once satisfied of this fact, naturally and eagerly springs to the inquiry, *how* these prodigious and appalling changes have been brought about,—changes by which strata of immeasurable thickness, which were once horizontal in the depths of a former ocean, have not only been raised out of these depths, and to the height of thousands of feet above the level of our present sea, but have been, as it were, driven and dashed against one another, so as to present nothing now but a scene of inextricable confusion. It is the business of the geologist to understand and to interpret these phenomena, forming, as they do, the language in which the operations of nature are recorded, and out of the apparent confusion which prevails, to unravel and reveal to mankind the age of our planet, and the epochs that have marked its eventful history.

"But these are *speculative* inquiries, from which we, in *this* part of our survey, entirely abstain. * * * * It is enough at present to have *hinted* at the existence of phenomena to be unravelled, and revolutions to be ascertained; for then we become the more disposed to search for information in every possible quarter,—to concentrate every glimmering of light that can be discerned, and diligently to study that volume of nature from which alone we can learn what are the agents that have been instrumental in fashioning our globe into what we now find it,—so wonderfully and benevolently adjusted to the constitution and habits of the animal and vegetable creation which now occupies its surface.

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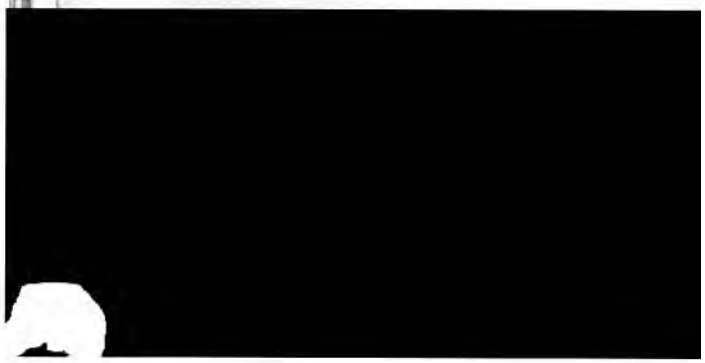


ON THE ANCIENT GRAUWACKE ROCKS OF SCOTLAND.

[By Hugh Miller.

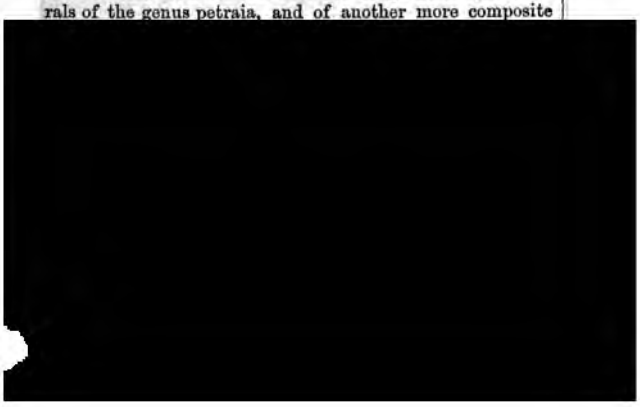
Read before the Royal Physical Society, 13th Nov. 1852.

PART SECOND (DESCRIPTIVE.)

As the traveller passes downward along the valley of the Girvan, the scenery, which had been hitherto of a pleasing, but purely Lowland character, begins to assume somewhat bolder features. The hills on either side heighten into heath-covered mountain ranges; and we remember that Scotland has its southern, as certainly as its northern Highlands. "The mountainous country in the south-western borders of Scotland," says Sir Walter Scott, in one of his novels, "is called *Hieland*, though totally different from the much more mountainous and more extensive district of the north, usually accented *Highland*." The bottom of the valley, however, which these hills overlook, is of a soft and pastoral character, with perhaps more of wood than is common in a Lowland valley, but laid out into rich fields that recline along the lower slopes, and occupied by a quiet stream,—the Girvan. Within a few miles of where it opens into the sea, we see on its northern side, high over field and meadow, a steep prominent range of gray crags, that at once remind us of those pale-tinted mural rocks of Silurian Limestone which form so striking a feature in the scenery of Dudley and its neighbourhood. And they, too, like the English precipices, are composed of a Silurian Limestone, rich in fossils. Far beneath, however, and in what at first seems an inferior position, we see rising among the trees the peculiar groupes of buildings, with their tall chimneys and long-armed engines, that indicate a coal-producing district, and mark on a sloping hill-side, immediately over a thick wood, a slim column of smoke ascending out of the ground,—where one of the seams beneath has been burning for years,—like the smoke of some subordinate volcano. The valley of the Girvan forms a deep and very irregular basin, composed of Silurian rocks, but occupied for several miles by a small though not unproductive patch of the Coal Measures, which abuts unconformably against the older deposits, and lies so low in the system as to be overlaid by the Mountain Limestone.

The explorer, in passing downwards, should strike off to the north from the public road, at the pleasant village of New Dailly, and rise on the hill-side, after crossing the stream, and passing the Castle of Dalquharran, towards the older rocks.

turning first, however, by the way, to visit the coal-workings immediately above the Castle, and then a little further on, to examine, in a chance opening among the trees, the overlying fossils of the Carboniferous Limestone. He would do well, however, if desirous to economize time, and make himself sure of seeing all in the district that is worthy of being seen, to secure the services of Mr Alexander M'Callum,—the ingenious fossil collector of Girvan,—under whose guidance he will learn more in a day than he could perhaps find out for himself in a week. Under the intelligent direction of Mr M'Callum, whose services Sir Roderick Murchison has deemed worthy of special acknowledgment in his paper, I struck up from the coal-works and overlying limestone and shale, in which well-known fossils, such as *Productus giganteus* and *Productus Martini*, may be detected, and reached the steep side of a rocky hill overhung by wood, in which several quarries have been opened, chiefly for the repair of roads. The rock, a dingy olive-tinted sandstone, which in colour and quality reminded me of some of the Caradoc sandstones, abounds in fossils,—at one place, where a deeply-shaded and rarely-trodden road has been cut into it, chiefly corals, apparently of the species *Favosites fibrosus*. But though, from their light colour, conspicuous on the dark rock, their state of keeping is usually bad. In a deserted quarry a little farther on, I found the Silurian forms in great abundance,—trilobites, orthoceratites, crinoidal stems, brachipods of the ancient genera orthis and atrypa, a large Maclurea, a bellerophon, casts of what seem to be turritella, a large trochus, and corals of the genus petraia, and of another more composite



dreary heath, I found the organic remains of the rock becoming still more numerous. Shells occur in beds and layers; and not in the rich limestone beds of Dudley have I seen them lie more thickly. The stone here is of a firmer texture than in the quarry, and, where unweathered, of a darker gray; and as the organisms which it encloses yield more readily on exposure than the surrounding matrix, they exist upon the surface as mere darkened casts, but in the fresh fracture are of a pearly white. And here also trilobites and corals occur among the shells. A little further on, the rock assumes yet a different hue;—it abounds in iron, which imparts to it in some places a deep red, in others a buff-yellow hue,—and the fossils, converted into a bright yellow ochre, present, when broken, an almost golden aspect, and are of great, though, from their state of extreme oxidization, of short-lived beauty. I have rarely seen anything richer in appearance than the bright yellow trilobites on a deep-red ground which I laid open in one of the higher lying quarries of the hill. They reminded me of the trilobites in the collection of a certain noble Lord now deceased, who became eccentric as he grew old, and, to improve their appearance, got them gilded and burnished. Sheets of festinella of the same bright hue that, when first exposed by the hammer, resemble pieces of gold lace, mingled with sprigs of golden coral, and deeply sulcated golden petraia, also occur in great abundance; with bronze-looking shells by the million, chiefly of the genera orthus, atrypa, and terebratula. So thickly do these lie in some of the beds, that they give to the otherwise solid rock a fissile character. One of the most remarkable-looking fossils of the group is, however, a large trilobite,—an Illænus, furnished with a caudal shield as large as that which covers its head, and of a decidedly Lower Silurian type, as are almost all the other accompanying organisms, though some of them have a wide range in the System, and occur in the lower beds of its Upper division. I may mention, that I found here, at the height of many hundred feet over the sea, the boulder clay, with its characteristic pebbles scored and polished, and in most cases bearing their striæ in the line of their longer axes;—that, in general correspondence with the average colour of the rocks of the district, it was of a deep gray colour;—and that its boulders were chiefly of Silurian rocks, charged with the characteristic fossils of the System.

Quitting the upper part of the hill, with its richly fossiliferous quarries, and striking downwards to the west and

south, I passed through a series of corn fields, and, on reaching a little stream which flows through a valley nearly parallel to that of the Girvan, found the rock partially exposed along its course. It consists here, not, as in the hill above, of an indurated sandstone, but of a gray rubbly shale, much broken by transverse *dries* and fractures, and which, though its relations to the sandstone are not clearly seen, seems, as premised by Sir Roderick Murchison, to rest over them. In localities to the south of the Girvan, as at Ardwell, Piedmont-Glen, and Peawhapel-Burn, it is rich in orthoceratites, and contains numerous beds of graptolites: in this locality, known as the farm of Drummuck, it abounds in tribolites. Mr Macallum had wrought out the exposed front, to which he introduced me, until arrested by a field fence, on which he was not permitted to encroach. But though I could procure, in consequence, no specimens for myself, I acquired several very interesting ones from Mr Macallum, which, with many others, he had dug out of this front; and I certainly at one time never expected to see a group of these curious crustaceans at once so ample and so characteristic, from the Grauwacke slates of Scotland. *Calymeni Blumenbachii*, the well-known Dudley trilobite, is the prevailing form of the deposit, —a form abundant, as its common English name testifies, in the lower deposits of the Upper Silurians of England, but which in North Wales also occurs in the Lower Silurians. I found associated with this trilobite, in the same fragment of shale, what seems to be a Forbesia,—hitherto exclusively an Irish form; and was lucky enough to procure a complete

sented by the typical *Graptolithus Ludensee*. Associated with these, but rarely, we sometimes find a large dark-coloured lingula, probably the *Lingula ovata* of M'Coy, also a Kildare species; and *Orbicula crassa*, a finely striated shell, bearing usually the same dark hue, as if both organisms had been covered by an epidermis, which had alone survived when their shelly substance had been absorbed in the rock. The orthoceratites of the deposit exist in a peculiar state of keeping. They have been converted, with the filling of all their chambers, into a pure chocolate-coloured lime; whilst the gray shale in which they lie is so little calcareous as to remain impassive under the strongest acids. Many of them seem to have been broken across ere they were committed to the rock, and exist as detached though very entire fragments, consisting of from six to ten chambers apiece. It is stated by Sir Roderick Murchison, that one of the largest of the Girvan orthoceratites being of a kind unknown to him, he referred it to M. Barrande, then on a visit to our country, who recognised it as a Bohemian species, occurring in the lower part of the Upper Silurian division. Sir Roderick adds, as further remarkable, that on submitting to the Continental geologist some of the shales and nodules in which these Ayrshire shells are imbedded, "he declared to him that he might produce our Scottish rocks as Bohemian specimens." The Bohemian species of orthoceratite has of late, I may mention, been found in Ireland by M'Coy.

Taking leave of the interesting shale deposit at Drummuck, I scaled the southern side of the little valley in which it occurs, and came down upon the range of bold limestone cliffs, whose picturesque appearance, rising high over the woods, had, at the distance of several miles, attracted my notice in the valley of the Girvan. The relations of this limestone to either the indurated sandstones or the trilobite shales is, from the covered character of the ground, not distinctly traceable; but its fossils belong to the Lower Silurian group, and it is identical in structure and appearance with a limestone which crops out in several localities to the south of the valley, and which, underlying the sandstone, is evidently the oldest deposit in the district. It is an exceedingly hard sub-crystalline stone, and looks as if an outburst of the trap rocks which rise around it, and at certain points send out enormous dikes into its substance, had given it, for the purposes of the palæontologist, rather too much of the fire. And

so, though it abounds in fossils,—corals, trilobites, and shells,—they are rarely sufficiently distinct enough to be identified. Occasionally, however, on the argillaceous surfaces of the thick beds of which the rock consists, we find a trilobite or shell impressed with characters sufficiently legible; and its more massive corals and encrinal stems are, from their lighter colour, and the trace which they still retain of internal structure, usually distinguishable enough in the body of the stone. It is a curious circumstance, that not only in the group do the fossils of this rock resemble those of the Silurians of Canada and the United States, but that some of its organisms not yet found in England seem to be even identical with those of the other side of the Atlantic. It contains a terebratula indistinguishable from a Canadian species, and a Maclurea determined by M'Coy to be the *Maclurea magna* of the United States. This last massive genus, which resembles that of Euomphalus, save that its whorls lie in nearly the same plane, is by no means rare in the limestones of the Girvan district, but so much so in the Silurians of the sister kingdom, that it does not appear in Murchison's great work. Some of our graptolites are also identical, it is said, with American species; and, on lately exhibiting my small collection of Scoto-Silurian fossils to a geologist of the United States, he told me that none of the organisms which he had yet seen in the museums of our country so reminded him, from their general appearance, of those of his own. It is surely not uninteresting thus to find the hitherto little known Silurian deposits of Scotland connecting its geology, by links not elsewhere found in Britain, with the geology of Bohemia on the one hand, and with that of the New World

I have said that the limestone cliffs of this deposit are singularly picturesque. At one point we find them traversed by a broad dyke of compact greenstone, which has been followed by the quarrier into the very bowels of the hill; and so, for several hundred feet together, we can see the yawning rent in the earth's surface which it had so lately filled, with its corresponding angles and its answering protuberances and inflections, existing as it must have existed when first torn asunder by the convulsion to which it owed its origin, and ere the molten matter had come boiling through it from the abyss. It is a wild recess, tapestried by mosses and overhung by brushwood; and from where it opens into the richly fossiliferous rock, in which lie entombed by millions the organisms of perhaps the earliest creation, the eye glances adown a noble valley, bosky with green woods, and chequered with smiling fields, and marks where it opens to the broad Atlantic, at busy sea-port town, or rests far beyond on the dim cloud-like Ailsa. When I last stood in its opening, at the close of a long summer's day delightfully spent, the broad sun, then resting on the far horizon, was casting its last red gleam on bush, and crag, and brown hill-top, and the deep slant shadows of evening lay stretched along the bottom of the valley. And then, as the light declined, the moon, in her first quarter, began to show her slender form through the dappled cloudlets, like a silver scimitar, and I saw her brightening image, as I passed, reflected on the stiller pools of the Girvan. How widely different must not the scene have been when those organisms of the rock lived at the bottom of their old Palæozoic ocean, and the light of that sun and moon,—mayhap the only unchanged objects on which the eye rested,—was caught by the many-sided eyes of the trilobite, or guided the carnivorous orthoceratite to its prey! Let me indulge for a brief space, ere I conclude, in an attempted restoration of the probable scenes and events of the period, in what is now Scotland.

For many ages, a wide ocean, from which the eye fails to see any shore, or the sounding-lead to find any bottom, rolls over what is now our country. Its profound depths, wrapped up in darkness, sink beneath the zero line of animal or vegetable life; and the fine gray mud, or light micaceous sand, that settles upon its unseen bottom, as the impalpable dust that mottles the sunbeam sinks on the floor of some deserted hall or old haunted chamber, scarce forms, after the lapse of years, a layer as thick as the roofing slate into

which, in these latter times, we find it consolidated. Gradually, however, and persistently, the deposition goes on. Besides,—under the deep-seated impulsions of the Plutonic forces, vigorous in their early youth,—there is a general rising of the platform. At length the light of day reaches it through the lessening space, in a dim green twilight, and it becomes a scene of organic existence. Vast fields of nameless algæ, still represented amid the rocks by our anthracite bands, embrown for many leagues the ocean bottom; and millions of zoophites, not higher in the scale than the modern pennatuladæ, which they not a little resemble, crowd every square rood of surface. And here, at wide intervals, some ancient terebratula fastens its fleshy cable to the rock; or there some lingula stands erect, flower-like, in its horny stem. There are changes taking place,—now gradual, anon abrupt. At one time death itself serves but to furnish fresh platforms for new life,—at another, through some subsidence in the general floor, the zero line of vitality is again reached, and over perished myriads, the dead sluggish strata settle down. At length, when unreckoned centuries—mayhap hundreds of centuries—have passed, the middle ages of the Lower Silurian period are ushered in; and when the Llandeilo flags and Bala limestones are in the course of deposition in what is now the principality of Wales, the transition limestones of Ayrshire are also gradually forming—in no small part—so abundant has life now become in the waters—of massive corals, and of the stony exuviæ of encrinites and molluscs. But to the period of this calca-

—each in succession, a home for the living, and a burying ground for the dead. And then yet another change takes place. The arenaceous deposit is succeeded by a deposit of gray argillaceous mud; the fauna, too, alters, in at least its aspect, and in the proportions borne in it by families and genera. Though in one certain bed, and for a comparatively short period, a small species of terebratula abounds, the brachipods generally greatly decrease,—a consequence, mayhap, of the altered nature of the bottom, now considerably softer than before; but, on the other hand, the cephalopeda, represented chiefly by the orthoceratites, very much increase, and the trilobites attain to their numerical maximum. Scales of fishes, somewhat resembling the bony plates on the sides of the sturgeon, have been found by Mr M'Coy in the Silurians of Ireland, in a deposit at least as old as these shales; whereas the system in Scotland has hitherto failed to yield any trace of the vertebrata. But though not yet prepared to demonstrate that fishes swam in this corner of the ancient Scoto-Silurian ocean over the argillaceous shales, these must have been traversed by many a restless mollusc and crustacean, —the one-chambered bellerophon, and the many-chambered orthoceratites,—by Calymene, Cheirurus, and Phacops, with their nicely-adjusted armour of many joints,— and by the massive Illænus, with its double buckler. With this upper formation of the Lower Silurian division, deposition in the earlier Palæozoic period seems to have ceased in this district. Farther to the south, however, on the shores of the Solway, the shales, in a somewhat altered form, pass into the lower beds of the Upper Silurian, and exhibit some of its characteristic fossils. And with these, the Old Grauwacke record, as a record of life and death, abruptly closes in Scotland, and a chapter of purely physical revolution begins,—a chapter perplexed by passages of doubtful meaning, and by many different readings, but which tells in every page, of widely-extended convulsion and upheaval, and of the operations of deeply-seated forces of a power incalculably great.

During the ages of either the Upper Silurian or the inferior Old Red Sandstone, the deposits of the Lower Grauwacke division in Scotland seem to have been the subject of enormous lateral pressure, which raised their strata into many folds and ridges over wide districts, and, as there is reason to believe, elevated them above the sea level. Sir Roderick Murchison reckoned in the neighbour-

and darkness at once envelope the land upon which they grew, we may be permitted to indulge at least in the provisional belief, that its framework was formed of our convoluted Lower Silurians, already existing as solid rock, and charged, as now, with the remains of a creation that had perished—that it was encircled by an Old Red Sandstone ocean, inhabited by fishes of uncouth form and gigantic size, and that it presented on its sloping hill-sides its primeval dawnings of the vegetable kingdom, now to the dews of the night and now to the light of day. Who would not wish to know somewhat regarding the geography, and the organisms, vegetable and animal, of this ancient land of the Lammermoors and Scotland emphatically of the olden time? But save in a few tattered fragments, its chronicles have perished, and we can but darkly surmise, from the existing evidence, that such a land there once was.

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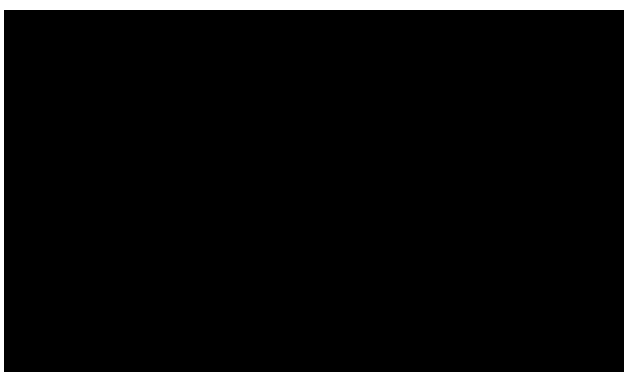
* I owe a characteristic portion of a fern frond from the Upper Old Red Sandstone of Berwickshire to the kindness of the discoverer, Mr John Stewart, Abercrombie Place, Edinburgh,—a zealous and successful labourer in the geological field. It bears the red hue of the stem, just a little darkened, and the vernation is not preserved; but in general outline it resembles a fern of the Coal Measures, *Sphenopteris polyphylla*.



THE FOSSILIFEROUS DEPOSITS OF SCOTLAND.

BEING AN ADDRESS TO THE ROYAL PHYSICAL SOCIETY,

DELIVERED ON THE 22D NOVEMBER 1854,

BY HUGH MILLER.

(First Half.)

GENTLEMEN,—It is customary for the retiring President, in taking leave of the chair, to address the members on some general subject connected with the objects which our Society has been instituted to carry out; and in conforming to the practice, I shall take the liberty of stating, as briefly as possible, the results at which I have arrived, in recently arranging the specimens of a collection perhaps more adequately representative of the Geology of Scotland than any other that has yet been made. There are other collections which, though more partial in their character, excel it in particular departments; but none which I have yet seen sweep so completely across the entire scale of our Scottish formations; and as such of its divisions as are most defective indicate, negatively at least, by the blanks on their partially filled shelves, the deposits on which we have still to direct our energies, it may be well that your attention should be specially called to these, as fields in which work has still to be done, and in which the reward of fresh and interesting discovery awaits the patient labourer. I am not sure that we need warmly congratulate ourselves on the fact,—but certainly a fact it is,—that the geologic section of our Society is in no great danger of exhausting its work at home for a very considerable time to come. We have still much to do in acquainting ourselves with the extinct productions of our country in those remote pre-Adamite periods of its history, when it existed, now as a group of Pleistocene islands,—now as a land covered by the Oolitic forests, and washed by seas tenanted by the ammonite and the naulitus,—now—ere yet its existing mountains had arisen from the abyss—as a series of dark plains and steaming morasses, brown with the rank and dusky vegetation of the Carboniferous period,—now as an extended sea-bottom, muddy or arenaceous, swum over by the strange ganoids of the Old Red Sandstone, and with here and there a minute island, green with—so far as it is yet known—the earliest ferns and the oldest trees,—and now as the bottom of a sea profounder still,—a sea without visible shore, inhabited

by the minute brachipods and unique crustaceans of the earlier Silurian ages. That history of Scotland which, omitting the human period as too modern, stretches backwards from the recent shells of the old coast line to the olenus and lingula beds of Girvan, and which is still unwritten, save in the rocks, will give our younger members work enough thoroughly to decipher and transcribe for perhaps a quarter of a century to come.

On first setting myself, about fourteen years ago, to add to my collection a set of Silurian fossils, I had to content myself with specimens derived chiefly from England and America. All the organisms detected at that time in the great Silurian deposit of Scotland,—though Sir James Hall had found shells in the Wrae Hill limestone nearly half a century previous, and Mr Charles Maclaren in the Silurians of the Pentlands at least *six* years previous,—would scarce have half filled a single shelf. Now, however, our old obstinate Grauwackes are yielding their organisms,—Dumfries, Galloway, and Peebleshire their graptolites, and Girvan and its neighbourhood its trilobites and its shells. The shores of the Solway near Kirkcudbright are furnishing, though still inadequately, their fossils of the *Upper* Silurian; and it seems not improbable that the Girvan locality may be yet found to furnish characteristic specimens of all the various deposits of the *Lower* Silurian, from those emphatically ancient beds, beneath which only a single organism has yet been detected, up to those superior deposits of the Lower division, in which the Dudley Trilobite (*Calymene Blumenbachii*) occurs, and which Sir Rode-

[redacted]

distance, must be held to possess a peculiar interest, from the circumstance that, though some of its more curious fossils have not yet been found in the amply developed and well-sought Silurians of England, they occur in those of Bohemia on the one hand, and of Canada West and the United States on the other. They thus form in the general history of the globe a connecting link between deposits considerably more than four thousand miles apart. I may add that, during the last few years, I have been able to place in my little museum, beside its Silurian fossils of America and England, a not less ample collection of the Silurian fossils of our own country, which, though still inadequate, contains several rare organisms, with which, so far as is yet known, the English deposits could not have supplied me. Still, however, much remains to be done in this curious field. I was shown only a few weeks ago, by a gentleman from the neighbourhood of Lesmahagow, specimens of a fossil crustacean, derived, he said, from the Grauwacke of that neighbourhood, which, so far as I could judge from their state of keeping, are new to Scotland, and which very considerably resemble that Hymenocaris of North Wales, which Sir Roderick describes in his Siluria as a true primordial fossil. And where the crustacean occurs it is more than probable that other organisms will yet be found.

The Lower Old Red Sandstone of Scotland has been more thoroughly wrought out than perhaps any of the other formations of the country, and it occupies, in consequence, a larger space in my collection. I have not yet found fossils in the Great Conglomerate, which forms its base; nor perhaps could organisms, save of the most robust structure, be expected in a rock formed of great water-rolled pebbles, which, ere they could have assumed their present rounded forms, must have been tossed by the storms of ages. In the pebbles themselves, however, we have curious glimpses afforded us of the old metamorphic rocks of Scotland, which were, we find, considerably different in the group from the rocks of similar origin which in the present age of the world compose our great Highland nucleus. The schistose gneisses, now the prevailing metamorphic rocks of the kingdom,—for they occupy nearly ten thousand square miles of its area,—were then but feebly developed, compared with its many-coloured porphyries, its granites, and its quartz rocks. In the Forfarshire Conglomerate, the prevailing rocks are hard porphyries, of an infinite variety of hue, and indistinguishable in their composition from the porphyries of Ben Nevis and Glencoe;

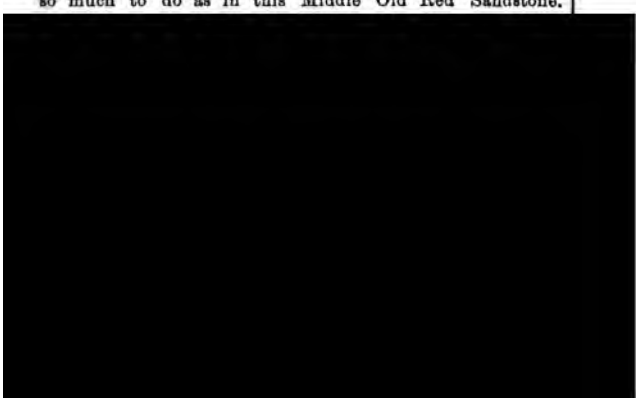
in the Conglomerate of Cromarty and Ross, a decaying granite, red like that of Peterhead, but as finely grained as that of Aberdeen, blent with red quartz-rock and red granitic gneiss, is the prevailing stone; in that of Orkney, as exhibited in the neighbourhood of Stromness, the prevailing rock is also a red granite somewhat larger in its grain, and more durable, than the Cromarty one. The stone which composes many of these enclosed pebbles can no longer be found *in situ;* and a good representative collection of at least the classes of rocks which they exemplify would serve to show the nature of the framework of that ancient unknown land to whose existence the Great Conglomerate bears evidence, and which, as over many thousand square miles the pebbles present the worn and rolled character, must have been exposed, zone after zone, during a protracted period of gradual depression, to the incessant wear of the ocean. The Conglomerate seems to have been exposed in an after period to intense heat. We find many of its hardest pebbles bent and indented, as if they had been reduced to the consistency of dough, or distorted by miniature faults, which scored their lines of fracture with the ordinary slicken-sided markings, when they were in a state viscid enough to re-unite. The fact would have been deemed a very great one during the heat of the controversy waged in this city between the antagonist schools of Hutton and Werner; but it is not less interesting now, when it can be looked at more quietly; and so I have given to a series of the pebbles which illustrate it a place in my collection.

Above the upper beds of the Great Conglomerate, at dis-

least one unique specimen, a true wood of the araucarian family,—the oldest which has yet presented its structure to the microscope. In some localities,—such as Cromarty, Thurso, and perhaps Moray,—the various ichthyic species of the formation seem to have been pretty nearly ascertained and collected: for several years I have not succeeded in disinterring from the several Cromarty deposits a single new species; and my friend Mr Dick, though permanently resident on the spot, has had a similar experience at Thurso. Species of the rarer kinds may, however, long elude very assiduous search, and yet turn up at last; and, in the course of the present twelvemonth, I have received from a tract of shore near Cromarty, which I have walked over many hundred times, an ichthyic species,—the *Diplacanthus crassispinus*,—of which my collection had possessed no previous specimen. I owe it to the kindness of Miss Catherine Allardyce,—a lady who, to a minute knowledge of not a few other branches of natural science, adds an intimate acquaintance with the fossils of our northern formations, and whose skill in zoophytology the late lamented Dr Landsborough has acknowledged in his interesting History of British Zoophytes. Further, it is worthy of remark that, just as the naturalist cannot now acquaint himself with all the animals or plants of Scotland in any single locality, so all the fossil species of any one formation cannot be exhausted in any one limited field or district, but must be sought for in various districts ere the list can be regarded as tolerably complete. The old Devonian species of fishes, like those of the present day, had their favourite haunts, and feeding or spawning grounds, and must now be sought for where they congregated of old. The *Diplacanthus striatus*, for instance, is one of the commonest of the Cromarty Old Red fishes, and the *Dipterus* and *Asterolepis* very rare; whereas at Thurso, Mr Dick, after years of exploration, never found a single spine of *Diplacanthus*, but not a few noble specimens of *Asterolepis*, and finely-preserved skulls and jaws of *Dipterus*. And in a neighbouring locality, Banniskirk, *Dipterus* is the prevailing fish, and may be found by scores. Again, the Old Red of Caithness generally is poor in specimens of *Pterichthys*,—the rocks of Thurso have not yet furnished a single specimen; whereas in those of Moray the genus is not rare; and in a quarry a few miles to the north-east of Stromness it is more abundant than any of its contemporaries. I mention these facts to show how necessary it is to the Palæontologist who sets himself to exhaust the organ-

isms of a formation within even a single country, that he should either be a sedulous traveller, or have a widely-located circle of friends engaged with him as fellow-labourers in the work.

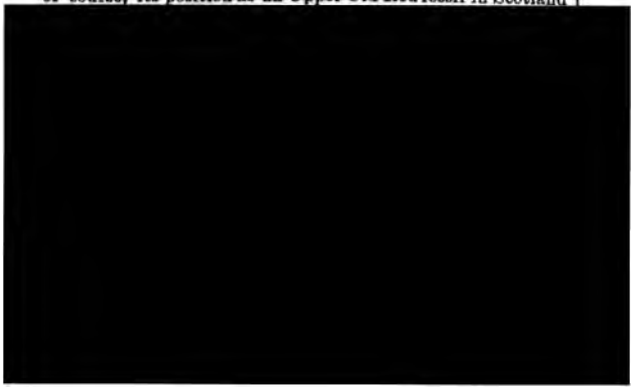
No ichthyic species of this Lower formation of the Old Red Sandstone has yet been detected in Scotland to the south of the Grampians. In the great belt of Old Red which traverses the island diagonally, from the coasts of Kincardine and Forfarshire on the east, to those of Renfrew and Ayr on the west, the fossils—restricted very much to the gray sandstones of the deposit—are of an entirely different group. Here, as in the immensely developed Cornstones of England, the prevailing and most characteristic organism is the *Cephalaspis*, which has now been found in Forfar and Kincardine shires by Sir Charles Lyell, Mr Webster, and others; in Stirlingshire by our ingenious brother member Mr Alexander Bryson; and in Ayr by the late Dr Brown of Longfine,—all, however, in the same gray beds of micaceous sandstone represented by what is known as the Arbroath pavement, which, like the red deposits that lie over and under them, run from side to side of the kingdom. While the fossils of the Lower Old Red Sandstone are more adequately represented in my collection than those of any other Scottish formation, the fossils of this Middle Old Red are almost the *least* adequately represented. And in this respect it resembles every other collection yet made, except that of Mr Webster, now, I understand, in the possession of Lord Kinnaird. There is perhaps no Scottish formation in which the Palæontologist has still so much to do as in this Middle Old Red Sandstone.



termine whether in Scotland, as in England, we have more than one species of this singular genus. Dr Fleming found in this Middle Old Red formation an apparent fern, with kidney-shaped leaflets; and it yielded several years ago, near Clockbriggs, in Forfarshire, a large specimen of *Lepidodendron*, which exhibits the internal structure. I owe a fragment of this fossil to an intelligent geologist, Mr William Miller, banker, Dundee; but so imperfect is its state of preservation, that, though it presents to the microscope the large irregularly-polygonal cells of its genus, it bears none of the nicer specific marks which might serve to distinguish it from the several greatly more modern species which occur in the Coal Measures.

Above this Middle formation lies the Upper Old Red Sandstone, with its peculiar group of organisms, chiefly fishes. And of it, too, much remains to be known. Save that it has not yet produced a *Coccosteus*,—a genus which seems restricted to the oldest ichthyic group of the system,—its fishes more resemble those of the Lower than of the Middle Old Red. It has its three species of *Pterichthys*,—its *Diplopterus*,—and apparently its *Dipterus*; and its Celacanths, chiefly of the Holoptychian genus, represent not inadequately the Celacanths of the genera *Asterolepis* and *Glyptolepis*, which occur chiefly, though not exclusively, in the Lower formation. The two formations seem, however, to have no *species* in common. In looking over the fine collection of Mr Patrick Duff, derived chiefly from the Scat Craig, in the neighbourhood of Elgin, I found only a single ill-preserved gill cover,—seemingly that of a *Dipterus*,—which I could not at once determine to be specifically different from aught produced by the inferior deposit. Rocks of this Upper formation have not yet been detected in Scotland to the north of the Moray Frith; and its richest British deposits are to be found in Moray, Perthshire, Fife, Berwickshire, and Ayr. In the collection of fishes from Dura Den, exhibited four years ago before the British Association, then assembled at Edinburgh, I saw several Celacanths that have not yet been described; and a good deal has still to be done in fixing and restricting some of the genera of the formation already named and figured. It will be found, for instance, that Agassiz's genus *Placothorax*, and his two species, *Coccosteus maximus* and *Pterichthys major*, will ultimately all resolve themselves into the latter species alone,—*Pterichthys major*;—of which, by the way, vast numbers have recently been found, though in a broken state, in the Upper Old Red Sand-

tone of the "Heads of Ayr." We may of course expect, however, to see more species and genera added to the group than subtracted from it. I must mention, ere concluding this part of my subject, a curious fact connected with the Flora of the formation. When visiting last spring the Museum of Economic Geology in Jermyn Street, under the friendly guidance of the late Professor Edward Forbes, he pointed out to me an interesting group of plants, in a fine state of keeping, which had been derived from the Old Red Sandstone of Ireland. The genera seemed identical with those of the Coal Measures, but all the species were different. I marked, among the others, an elegant Cyclopterus,—*Cyclopterus Hibernicus*,—of which Sir Roderick Murchison figures a single pinna in his recently published "Siluria." The Professor also introduced me to the only ichthyic organism that had been found in the Irish deposit, with the plants, a ganoidal fish, apparently a Celacanth, and very much of the type of those of the Upper formation, though I failed to identify the species with any of those already known. Professor Forbes, in return, visited my collection here only a few weeks ago; and in a fern of this Upper deposit, laid open by our ingenious member, Mr John Stewart, in Prestonhaugh quarry near Dunse, he recognised his Irish Cyclopterus. As Mr Stewart found the Scotch specimen associated with plates of *Pterichthys major* and scales of *Holoptychius Nobilissimus*,—two of the most characteristic ichthyolites of the Upper formation,—there can be no hesitation in assigning to it its place in the scale; and, of course, its position as an Upper Old Red fossil in Scotland



Indeed, he had traced a considerable resemblance between the scales of *Stagonolepis* and those of a ganoid of Dura Den, —the *Glyptopomus*. They bear, however, a much closer resemblance to the scales of the *Mystriosaurus Muinsteré*, a reptile of the Lias of Munich, of which I exhibited a good print to this Society about three years ago, the use of which I owed to the kindness of Sir Charles Lyell. When visiting a quarry in this northern deposit several years since, I was informed by the workmen that they frequently came upon foot-tracks like those found by Captain Brickendon. The only other remains of the deposit is that of the reptile *Telerpeton;* and when we take into account the fact that in this northern locality outliers of the Lias and Oolite are not unfrequently found resting conformably on the Old Red Sandstone, and that the vertebrate organisms of these deposits are preponderatingly reptilian, it seems at least as probable that it belongs to that Secondary period of the world's history during which reptiles were abundant, as to that middle Palæozoic period during which, though fishes were largely developed, reptiles were exceedingly rare. But the final determination of the point must be regarded as awaiting the researches of the future.

The Carboniferous deposits in Scotland have, from their economic importance, been longer wrought than those of any of its other systems, and yet all their fossils, animal and vegetable, are still far from being adequately known. During the last few years I have found the remains of both plants and animals in Carboniferous deposits, not many miles removed from our Scottish capital, that have still to be figured and named; and much remains to be done in the work of restoring from suites of specimens, organisms of the system, both vegetable and animal, already known in part. It is only within the last two or three years that trace of reptiles has been detected in our Scotch Coal Measures. The *Prabatrachus colei* of Owen has been found in the coal-field near Carluke; and the footprints of a much larger reptile detected in our Dalkeith coal-field by Mr Henry Cadell, the experienced and intelligent mineral surveyor of his Grace the Duke of Buccleuch. I refer to these interesting facts to indicate the direction in which there is encouragement to press our researches. We have hitherto had little experience in Scotland of that style of exhaustive research of which the Palæontographical Society of England is presenting us with so admirable an example. Curiously enough, however, old David Ure, one of our earliest collectors of the Carboniferous fossils, gave, in his Natural History of Rutherglen, published more than sixty years ago,

an example of this exhaustive style, perhaps as complete as was possible at the time. He seems to have figured, and, after a sort, described, every fossil of both the Coal and the Mountain Limestone, which he succeeded in disinterring during what—in an age in which there were few to sympathize in his labours—must have been a very sedulous course of research. The magnificent sections of our neighbourhood give peculiar facilities in exploring the Coal Measures and their contents,—facilities which geologists who have resided for a season amid the soil-covered flats of central England would well know how to appreciate. There are few finer sections of the Coal deposits anywhere in Britain than those laid open along the shores of Granton, Musselburgh, and Prestonpans; and the section of the Mountain Limestone exposed in the ravine at Dryden is, so far as I have yet seen, the most extensive in Scotland. By those who hold, as is done by some of the geologists of our western capital, that this formation is wanting as a base to the Scottish Coal-field, a visit to this section might be found very instructive. It does not exhibit that great thickness of limestone for which the corresponding formation in England is so remarkable, but presents, for several hundred feet together, in its encrinal bands, intercalated amid shales and sandstone, evidence of a marine origin; and its upper calcareous beds, laden with spirifers and producta, and of very considerable thickness, show that a tolerably profound sea must have covered the field shortly ere the formation of our older beds of workable coal.

THE FOSSILIFEROUS DEPOSITS OF SCOTLAND.

BEING AN ADDRESS TO THE ROYAL PHYSICAL SOCIETY,

DELIVERED ON THE 22D NOVEMBER 1854,

BY HUGH MILLER.

(Second Half.)

My collection contains no specimens of the New Red Sandstone of Scotland,—the scene of those discoveries of the late Dr Duncan of Ruthwell, from which that division of geologic science known as Ichnology took its rise. Nor are at least *sets* of its specimens to be found in any of the Scotch museums I have yet seen; but as Sir William Jardine is understood to be still engaged in figuring and describing its various footprints,—the only traces of former existence which it has been found to contain,—we bid fair to be acquainted, at no distant date, with all that it produces. It could be wished, however, that we had the result of Sir William's labours conveyed to us in that cheap, but yet adequate, form of outline engraving, in which Professor Hitchcock has figured the foot-tracks reptilian, or ornithologie of the New Red Sandstones of Connecticut.

In the Lias and Oolite of Scotland a good deal still remains to be accomplished. Some of their richest deposits lie scattered among the inner Hebrides, and along lochs and creeks of the Western Highlands, rarely visited by the tourist, and far from inns; and this difficulty of access has served to lock up in these solitudes many a curious fossil, that may be regarded as held in safe keeping, to reward the enterprise of our younger geologists. My collection contains not a few curious specimens derived from these Hebridean recesses during a desultory voyage in the Free Church yacht Betsie, made about ten years ago,—reptilian remains, fossil wood, and the teeth of placoidal fishes from the Oolite of Eigg, and pinnæ, ammonites, and massive corals from the Lias of Pabba and Skye. It may serve to show that we are no more to argue an entire identity of the Oolitic deposits of Scotland with those of England, than of its Silurian with the Silurians of that country,—that corals, which are of exceeding rarity and minute size in the English Lias, form entire beds of great extent and several feet in thickness in the Lias of Skye. I can, however, only indicate the locale of some of the deposits in which these rarities may be found,

—simply referring, in the passing, to the localities already indicated by Sir Roderick Murchison in his earlier papers,—such as the Oolites in the neighbourhood of Portree, the Oolitic beds of Raza, and the Liasic strata of Applecross; as also to the curious fresh-water or estuary deposit of Loch Staffin described in the *Geological Journal* for 1851, by the late Professor Edward Forbes. There is a patch of Lias on the shores of Loch Aline, exceedingly rich in some of the characteristic organisms of the formation, which I would fain have examined, but wanted opportunity. From deposits partially overflown by the Trap of Mull, and which crop out along the eastern shores of that island, I have exhumed specimens that bear in the group an Oolitic aspect; and in spending a few hours in the island of Pabba, when the yacht, my home for the time, was cruising in the offing, I found in it such promise of a rich fossil harvest, that when a young friend,—Mr Archibald Geikie,—requested me last year to point out to him some one or two centres from which I thought he might best acquaint himself with our Scottish Lias of the western coast, I ventured to recommend the latter island, and the southern portion of the neighbouring Bay of Broadford, as two of the most promising. Mr Geikie,—in whom our Society may, I trust, recognise a future member,—found his way to Pabba,—introduced himself to the sole family resident on the island,—slept, I believe, in a barn,—lived on potatoes and milk,—and brought away with him an interesting suite of fossils. And after this manner must the Hebrides and the Western Highlands be explored. The Oolitic beds of the eastern coast are considerably more accessible

to determine the point, with that of the Perna bed described by the late Mr Robertson of Woodside as flanking the Brora seam. Above the coal there occurs a rubbly stratum, also like one at Brora, charged with vast numbers of the *Belemnite sulcatus;* and in an upper stratum I found a well-marked specimen of *Ammonites perarmatus;* likewise a species of the Brora coal-field. In short, I am disposed to hold,—both from the identity of many of its fossils, and its general appearance,—that this supposed Liasic deposit is in reality an Oolitic one, and that its coal occupies a horizon not much removed from that of the coal at Brora. I may here mention, that the Lias of Eathie was the scene only two years ago of a disastrous coal-boring speculation, on which much good money was expended. The unlucky speculator,—an industrious and respectable man, whom I would fain have dissuaded from an undertaking so hopeless, but who, as he had no faith in geology, simply thanked me for my advice, and wrought on,—dug a wide pit in the Liasic shales, to the depth of more than a hundred feet, and found in abundance ammonites and belemnites, with a few well-preserved vertebral joints of Ichthyosaurus, and unfortunately here and there fragments of cone-bearing trees, with their trunks converted into jet, but of course no coal. The hole was made large and deep enough to prove the sepulchre of several hundred pounds; but I console myself by reflecting that the inevitable expense of the excavating operations was incurred in defiance of all that I could say; and I would now urge on my friends the Anti-geologists, that they should much rather attempt making shillings by lecturing against the science, than run the risk of losing the shillings already made by becoming *miners* in its despite.

The Oolite of Sutherland,—famous for containing the only seam of coal in this formation, at least in Britain, which could have been wrought for years without much positive loss,—was elaborately described many years ago by Sir Roderick Murchison, in a memoir that gave rich earnest of his after contributions to geologic science. It is impossible, however, to exhaust a great formation otherwise than slowly; and not a few fossils have been added of late years to the list appended to Sir Roderick's memoir. It is from the vegetable organisms of this deposit that we can now form our most adequate conceptions of the Oolitic Flora of Scotland. As in England and America, it had its numerous cycadaceæ,—its ferns of simple undivided frond, different in their venation, but resembling in their forms the hart's-tongue genus (Scolopendra),

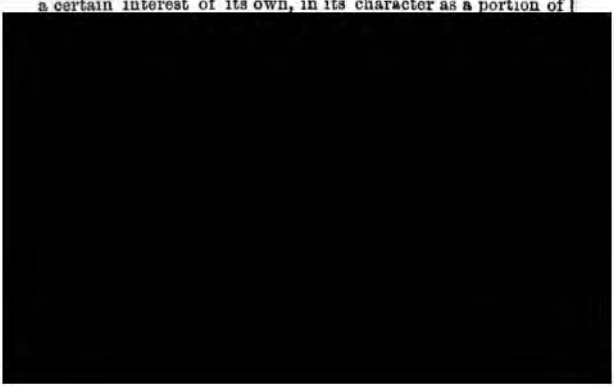
its thuyites, its pines; and, though they occupied a scarce appreciable space in the group, its dicotyledonous plants. When, after glancing over some of the vegetable productions of the system, such as its cycadaceæ, now restricted to the warmer climates, or over its massive corals, which attained to a size seldom rivalled in the present state of things, save in the intertropical seas, I have then examined some of its woods externally gnarled, and stunted, and marked internally by minute annual rings, as small as those of a Scotch fir or Norwegian pine that had grown on some exposed hill-side,—it has occurred to me that some of the Oolitic districts in what is now Scotland must have had their lofty mountain ranges, which, while a genial climate prevailed at their bases, rose, mayhap, to nearly the snow line, and bore on their bleak ridges the stunted slow-growing trees. The framework of this ancient land was composed—as we learn from its conglomerates, and in some instances from the fragments of rock still locked fast amid the roots of its trees—of Old Red flagstones, identical with those of Caithness, and evidently bearing at the time marks of as high an antiquity as they do now. Many of these flagstone masses, sorely water-rolled, occur in an Oolitic paste; and we find in strange neighbourhoods shells of the Oolite enclosed in the paste, and fishes of the Old Red in the pebbles which it envelopes. I have found a pebble which bore inside an Old Red *Osteolepis* encrusted with an Oolitic *Thamnatria;* and another pebble occupied by an Old Red fucoid that was partially perforated by an Oolitic lithodomus shell. It is surely not uninteresting thus to catch, as it were, glimpses, through the high antiquity of a Secondary age, of a Palæozoic

of a new species of *Hybodus*, the teeth of an *Acrodus* and *Sphenonchus*, the scales, and, at least in one instance, an entire specimen, of a *Lepidotus*, which Agassiz has identified as the *Lepidotus minor* of the English Weald, bones and teeth of *Plesiosaurus*, a well-marked chelonian femur; shells, both marine and fresh water, such as *Unio Planorbis Paludina*, what seem to be an *Astarte* and a small *Oyster*; and whole strata formed of a minute *Cyprus*. There are appearances connected with the Linksfield deposit that date from a comparatively recent period, which are at least as extraordinary as aught that the beds themselves contain. They form there a small hill, about from forty to fifty feet in height, and several hundred feet in extent either way; while beneath lies a thick deposit of the Old Red cornstones, wrought in this locality for lime. Interposed, however, between this hill of the Weald and the calcareous cornstones, there is a bed of the ordinary boulder clay of the district, charged not only with fragments of the rock on which it lies, but also of the well-marked Wealden strata which overlie it; and, more curious still, the cornstone bears on its surface, so far as the quarriers have yet penetrated, the ordinary glacial markings characteristic of the boulder clay. It would seem as if during the glacial period this hill had been so shifted or raised from its foundations, that the agent, whatever its nature, which during the icebergal period dressed and grooved the rock surfaces of the country, was enabled to dress and groove the cornstone on which it now rests. The appearances, suggestive of the operations of some incalculably enormous force, are suited to remind one of that sublime simile employed by Milton, in describing the effect of the stroke under which the rebel angel fell:—

> "As if on earth
> Winds underground, or waters forcing way
> Sidelong, had pushed a mountain from his seat,
> Half sunk with all its pines."

With these detached outliers we take leave in Scotland of the Secondary formations, in their character as original deposits, whose strata still occur in the order in which they were first laid down. We find, however, in Banff and Aberdeenshires, and more partially in Caithness, remains of the Cretaceous system, occurring in some localities in the character of re-formations. A deposit at Moreseat, near Cruden, elaborately described by Mr William Ferguson, late of Glasgow, seems to be almost exclusively a re-formation of the Greensand; and on the Hill

of Dudwick, near Ellon, there are vast accumulations of flints, in which the Rev. Mr Longmuir of Aberdeen, who has carefully explored the locality, detected many of the characteristic Cretaceous fossils furnished by the chalk of England. I have examined beds of gravel a few miles to the south of Peterhead, in which there occurs merely a per centage, though a not inconsiderable one, of these chalk flints; but I have been informed by our ingenious corresponding member, Mr Peach, with whom I saw several of the Cretaceous organisms of the locality, that had I set myself to examine in a different direction, more to the north and west, I would have found thick gravel beds, composed of chalk flints almost exclusively. The best collections yet made of the organisms of this denuded system, of which only the broken fragments survive, are those of Mr Longmuir, representative of the Scottish Chalk, and of Mr Ferguson, representative of the Scottish Greensand. Both are inadequately represented in my collection; and what it possesses I owe chiefly to the kindness of Mr Longmuir, and to that of Mr Dick, the original discoverer of the Chalk in Caithness, where it occurs, however, merely in detached fragments in the boulder clay. Much need not be expected from the organic remains of a deposit so broken and scattered. I have seen in its flints, however, finer and more delicately preserved specimens of a Flustra, that not a little resembles our existing *Flustra foliacea*, than any I have yet succeeded in detecting in those of England; and the group, however fragmentary and incomplete, must be regarded as possessing a certain interest of its own, in its character as a portion of



a comparatively late period, Scotland had its great outbursts of Trap. A thick bed of rudely columnar basalt overlies the most modern of these beds; and deposits of Trap Tuff, in which his Grace detected rolled chalk flints, overlie the older ones; thus showing, that long after the times of the Chalk, and when trees allied to the yew, the plane, and the buckthorn, grew in our forests, those deluges of molten matter from the abyss which had obtained throughout the earlier geologic ages had not yet ceased, but were, on the contrary, potent enough to overspread wide areas to the depth of from twenty to forty feet. From these times of fire we at once pass, in this northern part of the island, to a period of ice,—to the ages represented by grooved and polished surfaces, travelled rocks, boreal shells, and the boulder clay. Though, geologically, the period was one, it yields, I am disposed to think, evidence of three distinct successive stages.

The boreal shells of Banffshire (which occur at Gamrie in a finely stratified sand, two hundred and thirty feet over the sea, and at Castleton King-Edward in a similar deposit of very considerable elevation, and at least six miles inland), lie deep—though exposed laterally in sections—in the Pleistocene deposit. At Castleton I found the shells within a few feet of the underlying Grauwacke rock, and an immense deposit of beds of sand and clay, and over all a thick bed of partially consolidated ferruginous gravel lying above them. At Gamrie, though, from the great slope of the ground, the fact is less certain, they also seem to lie low; and further, both from their littoral aspect, and the circumstance that we find no trace of a littoral terrace where they occur, I cannot avoid the conclusion that they mark the line where a *shore* of the country existed for a time, when the country was in a state of subsidence, and ere yet the higher lying boulder clay was formed. The only peculiarity of the shells themselves, viewed in the group, is their intensely boreal character. The sole species of Astarte which I have yet found at either Gamrie or Castleton King Edward,—and I have now visited these deposits five several times,—is the Greenland shell, *Astarte Arctica; Natica clausa*,—a shell of Spitzbergen and the North Cape,—is the prevailing Natica; and the most abundant shell, of at least the Gamrie deposit, is a bivalve not yet found living in our seas, but common ten degrees farther to the north, *Tellina proxima*. Even the great size to which the latter shell attained in this locality is not without its bearing on the question. "The few specimens which have been dredged [dead] in Britain," says the late Professor Edward

Forbes, in his admirable history of the British Mollusca, "are much smaller than the exotic ones, none which we have seen exceeding three-quarters of an inch in length, and about half an inch in breadth." The mollusc is one of those which attain to their fullest development amid the frosts and snows of the higher latitudes; and it is a curious fact, that in the Gamrie and Castleton deposits we find it of a considerably greater size than anywhere else in Scotland. My largest specimens from the Clyde beds hardly exceed an inch in length; whereas my largest Gamrie specimens are nearly two inches long, and their *breadth* very considerably exceeds the length given as British by Professor Forbes.

Most of the boulder clays,—especially the higher lying deposits,—I regard as more modern than these Banffshire beds. They mark a period when the land sat low in the water, and existed as but a group of wintry islands. To the south of the Grampians, their organisms are but few; they have yielded at wide intervals horns of the rein-deer, and tusks of the northern elephant; but, save in an insulated patch in Wigtonshire, no shells. The boulder clay in Caithness is, on the other hand, rich in shells. They attracted the attention of a mineral surveyor, who flourished about the beginning of the present century,—old John Busby,—more than fifty years ago; they also attracted the notice of the late Sir John Sinclair; and in one of my Caithness journeys, I was told by my friend Mr Dick, that one of the hills on which they occur has borne from a still more early period, the name of "*Buckie's* Hill;" but to Mr Dick himself, and to Mr Cleghorn of Wick,

and scratches marks of the same agents that dressed the rocks and scored the pebbles;—nay, the very substance and colour of its prevailing clays show that it is mainly composed of the dressings of the rocks on which it rests,—all giving evidence, apparently, of a time when our half-foundered country sat from eight hundred to a thousand feet lower in the water than it does now, and vast packs of grinding icebergs went careering over what are now its lower hills and its higher table lands.

The Clyde beds and their contents belong apparently to a still later time. Their largest shells are usually in a state of great entireness and fine keeping. I had the pleasure of laying open, two years ago, at Fairlie, on the Ayrshire coast, a virgin deposit, unknown before, in which I found continuous scalps of *Pecten Islandicus* still occupying the place in which they had lived and died, and with their upper valves covered with large balanæ, such as we now dredge up from the outer limits of the laminarian zone, and all fresh and unbroken. Huge *Panopæa* were there sticking fast in an unctuous clay, with their open siphuncular ends turned upwards; and entire specimens of *Cyprina Islandicus* and *Modiola Modiolus*, with their valves still connected by the sorely decayed ligament. *Tellina proxima* was abundant, but reduced in size to little more than half the Gamrie dimensions. I found *Astarte elliptica* the prevailing astarte; and groupes of younger Cyprina huddled together in the character —which they do not now assume on our coasts—of gregarious shells. No crushing iceberg had passed over this deposit;—a grooved and polished rock of Old Red Sandstone lies beneath, overlaid by a thin stratum of red clay, apparently derived from it;—but the higher lying gray stratum in which the shells occur had a different origin;—it is simply the partially consolidated mud of a quiet sea bottom; and though its group of organisms manifest decidedly the boreal character, I cannot doubt that they lived at a time when, either from some change in the currents of the coast, or from the elevation of the protecting islands outside,—an effect of a general rising in the land,—the sea was no longer an exposed one. They in all probability mark that later stage of the wintry period to which the last formed group of our local glaciers belonged, and in which our gradually-emerging country presented, age after age, a broader and yet broader area, won from the deep.

One period more, and I shall have completed my survey. All the shells which have hitherto been found beneath our *latest terraces* of upheaval, still exist on our coasts. They re-

present a time, perhaps not greatly in advance of the earlier historic ages, when the country had begun to exist under its present climatal conditions. Some of these modern shells are, however, found to occur in very different proportions in certain localities from what they do now. The only specimens of *Pholas candidus* which I have been able to procure from the lower reaches of the Cromarty Frith, occur in a clay bed of the old coast period which underlies a wheaten field in the *Lones* of Fern, a full mile from the sea. My only specimens of *Scrobicularia piperata* from the Frith of Forth have been derived from the brick clays behind Portobello, more than a quarter of a mile beyond the reach of the tide. My first found Scotch specimens of *Thracia convexa* I collected last year from a raised sea bottom near North Queensferry. The upheaval of the land seems to have altered the conditions, in certain localities, favourable to the production of shells such as *Scrobicularia* and *Pholas;* and *Thracia convexa*, though it still lives in the Frith of Forth,—which furnished me in the course of last summer with two specimens, that, from their appearance, must have died within the twelvemonth,—seems to be a greatly less abundant shell in the locality now than during the ages of the old coast line, and appears, unless, indeed, it has been hitherto strangely missed by our dredgers, to be dying out. The old sea-bottom at Queensferry, little more than half an acre in extent, furnished me with full three dozen specimens, though in a state more or less broken; an extraordinary number, for what has been well described in the history of the Mollusca as one of our rarest British shells. Of these recent shells of the ancient coast

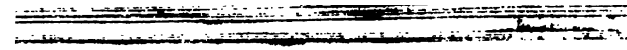
birch, alder, the Scotch fir, and the yew,—with handfuls of sorely blackened hazel-nuts, and the trunks and branches of a dwarfish hawthorn, converted into a glossy substance, nearly resembling jet. They yield us curious glimpses of those mighty woods which covered the country ere it had become a home of man, or during those earlier ages of his inhabitancy, when he was yet too unskilful to commence its history.

Such is a view, all too inadequate, and yet, I fear, not a little tedious, both of the several fields in which our geologic members have still much labour before them, and of what a Scottish museum, truly national, should represent. Though the breaks and hiatuses are many, there are still noble materials within the limits of our country for the composition of its pre-Adamic history,—that history of which the record is in the rocks, and of which organisms are the significant and impressive characters. The very gaps which occur in the long chronicle serve all the more strongly to divide it into periods, each furnished with its own independent group of being, specifically unlike that which went before, or that which followed after, and suited to remind us all the more emphatically in consequence, that to every species that ever lived in the old geologic ages there came a "last day." We have been long accustomed to recognise the inexorable reign of death in its relation to individuals, and to regard it as one of the most assured and certain of all things, that as all who have lived upon our earth during the ages of the past have died, so it is "appointed for all" who now live upon it "once to die." The same experience which leads us to anticipate that the sun will rise and set to-morrow, just because the sun has risen and set during all the many days of the past, leads us also to anticipate that all the individual creatures which now inhabit the earth will die, just because all the individual creatures which inhabited the earth in the bygone ages *have* died And we now find geology extending this uniform experience of death from individuals to species, and compelling us to believe, on the strength of the argument to which we so unhesitatingly yield in the other cases, that as all the *species* of the past have died, so it is destined for all the species of the present also to die. The theologian had to contend in the last age with a class of sceptics who,—their scepticism assuming, as is not very uncommon, the form of credulous belief,—used to argue that there had been an infinite series of men upon earth; and, of course, if the race had no beginning, could it be held in consistency that it was to have

an end? We now absolutely know, as geologists, not only that a beginning there was, but that that beginning was a comparatively recent event; and further, founding on the unvarying experience of the past, we also know that the race, in at least its existing character and condition, is to have an end. There are peculiarities, too, in the visitations of the present time, suited to suggest many a pregnant thought in connection with this curious and surely not unimportant subject. I travelled by railway, in middle autumn, two years ago, for about a hundred miles, through a series of well cultivated fields; and found almost all their potatoes, constituting about one-fifth of the entire produce of the district, killed by a mysterious disease, and exhaling a heavy odour of death and decay that infected the air mile after mile. There were perhaps as many individual plants of this useful vegetable lying brown and dead in the extensive area through which I passed, as the entire species would have consisted of had it not been so sedulously and extensively cultivated by man; and the appearance of the blackened and fetid fields suggested to me how, in at least some of the instances, species may have died. A disease similarly extensive is devastating at the present time the vineyards of the south; and it is said that should it continue its ravages for a year or two longer,—the generous *Madeira* of the wine-drinker will become as much a mere tradition in consequence, as the extinct wines of the ancients. Nay, during the present age, have we not seen a new and terrible disease, quite as mysterious in its character and origin as any of these which have fallen on the vegetable kingdom [redacted]

Royal Physical Society; and who had, since that time, achieved for himself in natural science in general, and in geology in especial, a reputation co-extensive with the civilized world.* But, alas! Death reigns. This distinguished man,—in the full blow of his fame, and in the mature prime of vigorous manhood,—has passed suddenly away; and wherever in either hemisphere physical science is cultivated, or the bypast history of our globe excites the legitimate interest, his early death will be felt and deplored as a heavy loss. The spoiler has broken abruptly off many a train of ingenious thought,—cut short many a course of sedulous inquiry,—arrested, just ere its formation, many a profound induction,—and scattered hoards of unrecorded knowledge, the adequate re-gathering of which many years to come may fail to witness. But our idle regrets can neither restore the dead nor benefit the living. Let us rather manifest our regard for the memory of our illustrious brother,—taken so unexpectedly from among us,—by making his disinterested devotion to science our example, and by striving to catch the tone of his frank and generous spirit. And seeing how very much he succeeded in accomplishing within the limits of a life that has, alas! fallen short by more than thirty years of the old allotted term, let us diligently carry on, in the love of truth, our not unimportant labours, remembering that much may be accomplished in comparatively brief space, if no time be lost, and that to each and all that "night cometh" at an uncertain hour, under whose dense and unbroken shadow "no man can work."

* It had been proposed, at the previous meeting of the Society, to call to the vacant Presidential Chair the late Professor Edward Forbes.



From the Glasgow Herald 14 Jan. 183[illegible]
Friday.

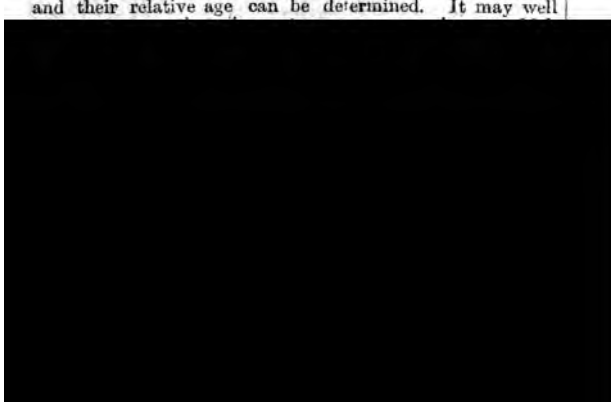
GLASGOW ATHENÆUM—LECTURE BY THE DUKE OF ARGYLL ON GEOLOGY.

Last night the Duke of Argyll delivered a lecture upon Geology, in the City Hall, Glasgow, under the auspices of the Athenæum. The hall was crowded, the reserved seats being occupied to a great extent by the fair sex of the city. Behind the platform and in front of the organ a series of gigantic diagrams were placed, having an effect at once instructive and ornamental. At a quarter past eight o'clock, the hour for the commencement of the lecture, Sheriff Sir Archd. Alison entered the hall, and made the painful announcement that the Duke had just met with an accident. In driving down from West George Street to Candleriggs (the place of meeting), the pole of a carriage had run into that which carried his Grace, and he had been cut on the head, though fortunately the wound was only slight. His Grace was now in the hands of a surgeon, but would be present in a few minutes.

The Duke soon after entered the hall, and was received with great applause. Happily, very slight traces of the accident to which his Grace had been subjected were apparent. On the platform we observed Sheriff Sir Archibald Alison, Walter Buchanan, Esq., M.P.; Sir James Anderson, M.P.; Sir James Campbell, Robert Stewart, Esq., of Murdostoun; Alex. Hastie, Esq.; William Campbell, Esq. of Tilliechewan; William Euing, Esq.; James M'Clelland, Esq.; Dr. Strang, James Gourlay, Esq.; James Lumsden, Esq.; Walter Crum, Esq.; David Hutcheson, Esq.; Sheriff Smith, Principal Barclay, Professors Allen Thomson, William Thomson, Nichol, Anderson, Macquorn Rankine, Roger; Bailies Wilson, Playfair, and Macadam; the Rev. Dr. Macleod, of St. Columba's, and several of the clergymen of the city; the Directors of the Athenæum, &c.

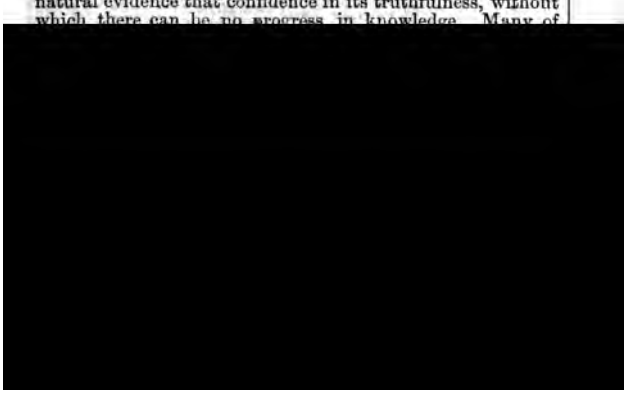
The Duke of ARGYLL, on rising to address the meeting, was again received with loud cheers. After apologising for the delay to which they had been subjected on account of the accident he had met with, he said—I have long been under a promise—I am almost afraid to say how long, but, I think, for the last five or six years—to the managers of this institution, to contribute towards its course of lectures. It was suggested to me that a more popular explanation than I gave to the British Association some years ago, of some curious facts connected with the basalts in the neighbourhood of Staffa, and Staffa itself, would form a subject more generally popular and interest-

ing. I prefer, however, on the present occasion to make that the last part of my lecture, and make the principal part of it subordinate to some remarks on the science of geology in general, its past history and future prospects, on the main conclusions which have now been formally established, and on some of those which are still the principal subjects of discussion and of controversy. The history of geology is a very short one, for of all the sciences it is the youngest one. Speculations, indeed, on the structure of the earth, and on the history of its creation, are old enough. Almost all mythologies contain them, and in all ages they have been a principal ingredient in what was called philosophy. But speculation is not knowledge, still less is it that systematic knowledge which alone we dignify by the name of science. By science we mean, not theories, not even mere acquaintance with individual facts, but that kind of acquaintance with them which consists in a knowledge of their relation to each other, and of the rule or law under which their occurrence is determined. Now, it is this kind of knowledge in respect of geology which is of such recent origin. There are, probably, some individuals in this assembly of whom it may with truth be said that their early years date from the period before the science of geology was born. It was only in the beginning of the present century that the foundation stone of geology as a science, properly so called, was laid, in the discovery of this cardinal fact, that successive periods in the history of the earth have been characterised by successive varieties of animal and vegetable life, that the remains of these have been preserved in the rocks which during these periods were in course of formation, and that by such remains the relative order of these rocks and their relative age can be determined. It may well



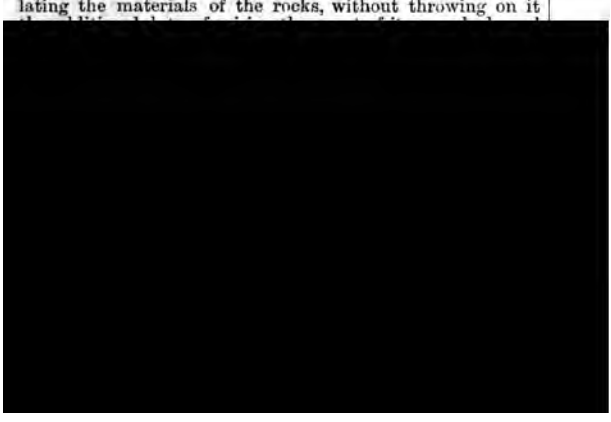
in themselves, will fail to do so. The very distance of the heavenly bodies, and the mystery of their movements, together with the splendour of their appearance, have, from mankind. Nowhere have they more naturally done so than in those countries whose inhabitants were the early cultivators of astronomy, where there is so little to distract the eye from the majesty of the heavens, and where the purity of the atmosphere reveals their wonderful phenomena with a brillancy that is unknown to us. But the rocks and stones of the earth, things which we are daily handling, or on which we are daily treading, what is there in these to rouse curiosity or excite to inquiry? To find out their physical properties or their adaptation to human use might seem the furthest aim of knowledge in regard to them. They are just what they had been made when earth itself was formed; and to seek their origin or history might seem like seeking the history of creation—a search which could only lose itself, and did actually lose itself, in misty speculations about the origin of matter. No wonder, then, that astronomy had the start of geology, on account of its greater claims on the curiosity of mankind; nor is it surprising, when inquiry had begun, it should have resulted comparatively soon in the discovery of truths beyond which there is even now hardly a glimmering of any probable kind. Astronomy, we must remember, is what is called an exact science. It is reasoning in its severest and most abstract form, requiring, indeed, the highest powers of mind for guidance and direction, but leading those who are able to follow it to conclusions with absolute certainty, and so to speak with mechanical precision. It is very different with geology. Its conclusions are built up from little gatherings on every side—upon probabilities and analogies—upon indirect and circumstantial evidence. The proof is not on this account the less perfect; only it is proof of another kind, requiring time, and the labour of many observers to collect and digest the evidence. And then some of those conclusions which we meet with almost on the threshold, are very difficult of belief. Take the very first. There is no habit of thought more born with us than that which leads us to place confidence in the stability of the great elements of nature; and especially on that relative distribution of sea and land, by which alone we recognise our home, our country, our very world itself. King David speaks of the "everlasting hills;" and such, indeed, they are—not merely in respect to the life of individual men, but in respect also of the life of all human generations. Small changes are perceptible in the course of centuries, and these may modify, perhaps considerably, the superficial aspect of a country. But we are accustomed to think, and to take pleasure in the thought, that all great natural features remain substantially unchanged. It is in this confidence that we visit the scenes of great events, and trace the outlines which were familiar to famous men. The very first conclusion to which we are led in geological science, is one which demands the surrender of all these notions of the stability of the land, and of the bounds within which the sea is stayed. It is no longer the "everlasting hills"—it is *only the* everlasting sea. We are called upon to believe, not *merely that* here and there the sea has gained upon the land, or *the land* has gained upon the sea—not merely that at some

given time the waters have covered the earth in sudden deluge, speedily retreating to their own bed again—but that in the long history of the globe, sea and land have been perpetually changing place—not suddenly, or, as it were, by accident, but frequently, almost regularly, as an ordinary operation of nature, and with intervals of rest as long and as peaceful as that which has now lasted since man was born. So hard of belief was this conclusion, that, although the constant occurrence of sea-shells imbedded in the rocks was one of the earliest circumstances which roused curiosity and excited to inquiry, men would not, and apparently could not grasp the vast idea. A curious example of the almost insuperable difficulty it presented, is to be found in a work, not much read now, by no less celebrated an author than Oliver Goldsmith. Among his many other literary labours—and incited, as he tells us, by admiration of the writings of Pliny—Goldsmith published in 1774 a treatise on Natural History, which, though not a work of original research, represents at least the condition of knowledge in his day. The universal diffusion of marine shells had attracted the notice of the ancients; and some of them appear to have drawn from this fact, conclusions which were inadequate indeed, but which made some approximation to the truth. Many, however, of the earliest modern inquirers had attributed the fact to the effects of the Deluge. Then, when on further consideration it had become clear that no merely superficial or transitory occupation by the sea could have deposited its productions deep in the bowels of the earth, incorporating them with the very substance of the rocks in which they are found, men were stupid enough to maintain that fossils were mere sports of Nature—things which had never really been possessed of life, although made in deceptive imitations of its forms. So grotesque a theory could not long stand investigation; and in the last century a number of writers had vindicated for natural evidence that confidence in its truthfulness, without which there can be no progress in knowledge. Many of



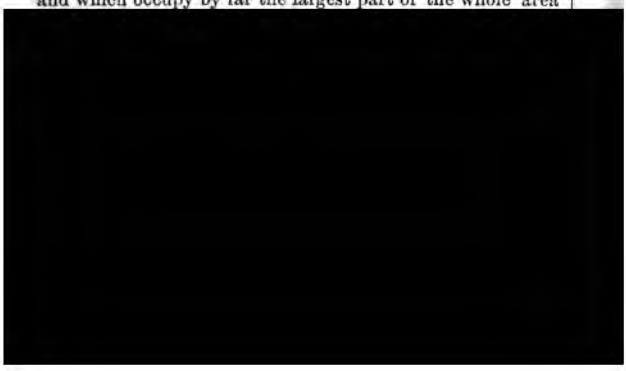
would seem to follow respecting the universal and continuous dominion of the ocean, that, in the choice of difficulties, he prefers the supposition that the shells which appear to have been marine may really have been only the produce of fresh-water lakes. Now, there are fossils which really have been left by lakes; but then they are at once distinguishable as such, by precisely analogous features to those by which we identify fresh-water shells at the present day. The characteristic distinctions between the productions of the sea and those of lakes, are just as certain and as constant as those which distinguish both from the productions of the land; and any theory which refuses to recognise this distinction, when it is apparent, is just as much a denial of the truthfulness of natural evidence, as that other theory which considered all fossils as jests of Nature. Goldsmith felt the difficulty, and only accepted it to escape from what he considered the still greater difficulty of supposing that the solid land—the great continents and highest mountains of the earth—had all at one time or another been covered by the sea. And it is well worthy of remark, that when men did begin to accept this idea, they accepted it under conditions very different from those which, as we now know, had really prevailed. Our ideas of the processes of creation naturally take their form from our own human methods of manufacture or design. We do not readily apprehend how slow and gradual are the growths of nature, and how their perfection and variety are what Tennyson calls the "long results of time." So, when the agency of the sea came at last to be recognised in the structure of the rocks, men imagined a sea very different from that of which we have any knowledge—some universal ocean, whose waters held all the materials of the earth in suspension—which had next let them fall, and then by its tides and currents had heaped them into mountains or scooped them into valleys. No wonder that Goldsmith, in reviewing these theories, speaks with some contempt of human ingenuity when engaged in what he calls the "amusement of earthmaking," and wishes that naturalists would "be content with giving us facts instead of systems." Facts however, are never so eagerly hunted out as when the search is undertaken in defence of some favourite theory; nor is the bearing of facts ever so well sifted as when some assumed interpretation is canvassed or denied. Goldsmith himself, in objecting to the theory of a universal ocean, refers to one fact of which due notice had not been taken. The very same rocks which testified to the dominion of the sea, testified very often quite as distinctly to the existence of dry land; for fossil-wood was as common as fossil-shells, and not unfrequently the wood seemed older than the shells, for they were lying underneath. However long, therefore, the sea may have rested on the land, said Goldsmith, it was clear that it could not have been either permanent or universal; and that, before the deposition of these rocks, the earth must have been covered with trees, and therefore "habitable, if not inhabited." Goldsmith was not far wrong here. Geology gives us no certain evidence of any time when the *whole* globe was covered by the sea,—of any *time when* there was no dry land; whilst the existence of *fossil-wood* and trees and leaves in innumerable strata,

proves, beyond the possibility of doubt, that the sea which deposited them was a sea with shores, and those shores covered, as such shores now are, with a terrestrial vegetation. Where, then, was Goldsmith's error?—what was it that puzzled him so much? The sources of his difficulty may all be traced in one word. He says that fossil-woods prove the earth to have been covered with trees. "The earth:" yes; but what earth? Not the earth which we now see in familiar outlines on the terrestrial globe; not Europe, Asia, Africa, or America—but some ancient earth, whose continents lay perhaps where the Atlantic lies now, and whose seas rolled over the area now roughened by the Andes or the Alps. The solution of the problem which presented itself to his mind is not quite so difficult as he supposed. He was not called upon to believe, as he thought he was, that the "sea had for a long time covered the tops of the highest mountains." No wonder he resisted this conclusion as inconceivable. So it is. But what he was really called upon to believe is very different. It is merely this: That the mountains of our earth, as they now exist, are, like other things, the birth of time; that there was a period, or more periods than one, when the materials of which they are composed had not been raised into the form of mountains—had not even been hardened into the consistency of rocks, but lay accumulating, as sand or silt or clay, in the bottom of primeval seas. In order, however, to conceive this, it was necessary to have an idea of some other agency than water for the raising or upheaving of the land. The horizontal, or nearly horizonal, position in which water tends to deposit its materials, could never be reconciled with the broken, twisted, or contorted form which the consolidated strata so frequently assume on land; and every attempt to account for such appearances by the action of mere tides and currents of the sea, were obviously futile. The se had quite enough work assigned to it in accumulating the materials of the rocks, without throwing on it



repeated cycle; new worlds being ever and again prepared from the waste and ruins of the old;—such was the theory of Hutton; a great advance on former systems, inasmuch as it rested entirely upon the operation of ordinary causes—that is to say, causes similar at least in kind to those which may be seen in continuous or occasional operation now. It was the first "Theory of the Earth" which contained something like an adequate idea of the incalculable ages of geological time. According to this theory, there was in the constitution of the globe a power for interchanging sea and land, the constant operation of which through unnumbered ages would account for any variety and extent of change. It was, in announcing this theory, that Dr. Hutton expressed himself in the famous sentence, the truth of which is even now a matter of discussion, and the discussion of which introduces us at once into the profoundest questions with which human science can be called to deal. Hutton denied that there were any rocks which could be called "primitive," if by this were meant rocks whose structure and composition could not be traced to the same origin as the rest. There were, indeed, strata which, being older than others, had been subject longer, and more frequently, to the agencies of change. But there were none which did not indicate the same ultimate origin—none which did not speak of a world still antecedent to themselves, from whose ruins their materials had been derived. There was, therefore, in geology, "no vestige of a beginning—no prospect of an end." But during the same years that Hutton had been devoting himself to the proof, and maturing of his Theory of the Earth, William Smith, an English land-surveyor, of very humble scientific pretensions, was working his way to the establishment of one great fact, which opened up an entirely new prospect to geological science, and is the foundation of all its subsequent marvellous progress. Dr. Hutton had clearly seen that the earth which we now inhabit, with its familiar divisions of sea and land, was but one of the thousand aspects which had been given to the globe in the course of time past, and that some aspect wholly different would result, in time still future, from forces which had been ever working, and were working still. To his eye it was an orderly procession of habitable worlds, in which, strain our vision as we might, no point of departure could be seen. But he had no suspicion of the fact, that the foot-prints which these worlds had left upon the "Sands of Time," contained within themselves a record of their place and order in the march of worlds, and perhaps, too, an indication of progress from a definite beginning towards a definite result. Yet it is curious how narrowly he and others had escaped this great discovery. He knew, and he dwelt upon the fact, that the worlds had left records of their existence in the remains of their animals and their plants. He knew, too, that those plants and animals could not always be identified with those which are existing now. But he passes lightly over this last fact, with the casual observation, that such differences as existed were no greater in kind or in degree than the differences which are found now between *contemporary species* in the living world. How often do we see, in the history of science, men having, as it were, their very hand on

treasures which it was reserved for some happier successor to recognise and secure! Little did Hutton imagine that, by measuring this difference of what he spoke so lightly, between the plants and animals of the present world, and those which were fossilised in the various strata of the earth, we have the means of arranging all past worlds in the order of their birth—a sounding-line by which to measure the abysses of past time; nay, more, a ray of light cast upon that darkest of all subjects, the History of Life. He has the honour of having first laid down the fruitful principle that the different strata of the earth could be best identified by their imbedded fossils, inasmuch as the shells and animals contained in each stratum were more or less exclusively peculiar to itself. His first map of the English strata, arranged on this principle, was published in 1799. By carefully following up the clue which this principle affords, and by means of analysis more and more refined, applied to the structure of extinct forms of life, the science of geology has now attained results with which, in respect to their grandeur, and the food they supply for thought, few other sciences can compare. I shall now attempt, as shortly and as clearly as I can, to state in abstract what are the most prominent conclusions which we may now consider as established, and what is the nature of the evidence on which the proof is founded. The rocks composing the crust of the earth may all be divided into two great classes—rocks which have been in the condition of melted matter from the action of heat, and rocks which have been formed by simple deposit from water. The fire-rocks are, in general, quite easily distinguishable from the water-rocks. Everybody knows "whinstone" and granite by sight, and these are typical specimens of the class to which they belong. As I have something special to say in respect to this class of rocks in the local description with which I shall conclude, we may at present confine our attention to that other great class of rocks which have been deposited by former seas, and which occupy by far the largest part of the whole area



great characteristics are seen in the rocks which have been formed by water; because it does so happen that in this country a very large proportion of the mountains are either not formed of stratified rocks at all, or of rocks whose stratification has been much obliterated and obscured by subsequent changes, and which are, for the most part, entirely destitute of fossil remains. But I wish I could give you by description any adequate idea of the magnificence and the distinctness with which, in some other parts of Europe, the mountains of water-rock speak to us of the origin of their materials. I have lately returned from a visit to the Austrian and Bavarian Alps, which are, to a great extent, entirely composed, from base to summit, of stratified limestone, and frequently so steep and precipitous that there is neither grass nor wood to conceal or obscure their structure. They stand up in stupendous precipices of perpendicular rock, all striped and ribanded with the parallel lines of original deposit—lines which no subsequent baking, or heaving, or fracture, or falling in has been able to efface. We know of one agency, and of one agency alone, whose mechanical effect is to arrange solid materials after this fashion—and that is the agency of water; and though the mind is oppressed by the idea of the long ages which must have been required for the accumulation, one above the other, of these layers of lime mud to the depth perhaps of 7000 or 8000 feet, still magnitude and time are the only difficulty; the effect on a smaller scale is seen, or may be seen, in the deposits of our rivers, and our seas. Nor are there wanting those other indisputable proofs of the reign of Ocean—the remains of its corals, and its shells, and its fish. On the occasion to which I have referred, we had before us, during the half of a day's journey, one noble mountain of most peculiar outline, which reared its sloping top, terminating on one side in a magnificent precipice, to the height of some 7000 feet above the level of the sea, and reminding us, more than mountains usually do, of the somewhat ideal forms in the pictures of Salvator Rosa. At the end of our day's journey we found that our halting place for the night was near its foot, and that it was a mountain celebrated for the fine view it commands over the surrounding Alps. Some of our party next day ascended to the top, and from high among its ledges of weathered rock, all roughened and honeycombed with the wear and tear of unnumbered years, they brought down fragments, some consisting entirely of broken shells, and others bearing on their surface, in the very form and position in which they had lived and died, the most fragile tenants of that ancient sea. There is still living, in some of our deep-sea lochs in the Western Highlands, a kind of shell called Terebratula, varieties of which have existed through a vast number of pre-existing worlds. It is a two-valved shell, like the common cockle, but has this peculiarity, that at the hinge one valve overlaps the other, and is provided with a small orifice, from which proceed little fibres, which serve to anchor the shell to stones or seaweed—only one species now existing in our seas. It is comparatively a rare shell; but I have myself dredged it in *Loch Fyne*, and it is to be found in other localities of *our western coast*. Well, here is a specimen of this peculiar *family of shells* which was found that day high up on one of

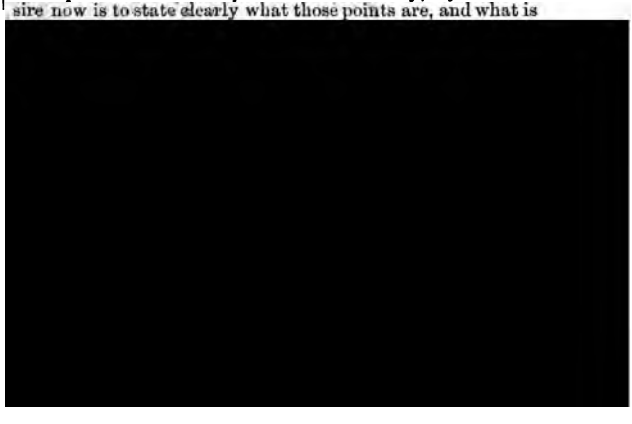
the weathered surfaces of the mountain. It is a small, delicate shell; yet there it is, as perfect as if it had been preserved in cotton, with the little orifice of its anchor as distinct as when it lived. It is clear that here we have it upon the spot on which it had existed, for it is too fragile to have borne transportation, unless for a short distance in deep and quiet water, and on a bed of soft and smooth material. No amount of reading, or of second-hand knowledge, can bring such conclusions so forcibly before the mind as scenes like these; and I confess I have never been so much impressed by the magnitude of geological phenomena as when looking at the mighty rampart of those Styrian Alps, separated by the main chain of the Alps from the nearest existing sea, yet bearing such visible evidence of the time when these materials were being accumulated in the great waters of some former world. But although it so happens that, in this part of Scotland at least, we have no mountains which exhibit so distinctly the stratified arrangement, and the peculiar fossils of the water-rocks, precisely the same phenomena are to be found close to the spot where we are now assembled. They happen to be less conspicuous, because the strata, instead of having been lifted and broken into the form of mountains, are comparatively little elevated, and are covered by the soil. But you have only to look at the sections of strata through which our coal-mines pass, to see precisely the same evidence of that peculiar arrangement in parallel beds or strata which characterises the water-rocks. I very well recollect that before I took much interest in this branch of science, I used to imagine that the representation of strata which we see in geological drawings and sections, was an ideal representation, and that in nature one did not see the rocks arranged in such precise and parallel lines. It is possible that there may be many here who have seen only the apparent confusion of the superficial materials of the earth—its soils, and stones, and fragments—and who are under the same impression. To disabuse them of this idea, I need only point out these actual sections of the rocks cut

would probably see that the river would cease to be navigable by vessels of any considerable size. The deposit which the river has laid down forms a very large portion of the ground on which this city of Glasgow is built, and we have the means of measuring all the strata which have been formed since our rude forefathers first began to navigate the Clyde. Mr. John Buchanan has kindly furnished me with a statement as to the fossil canoes which have been found in the strata formed by the deposit of the Clyde. It appears that during the last eighty years no less than seventeen canoes have been discovered. One of them was found in digging the foundation of St. Enoch's church, twenty feet below the ground. Another was found at the Tontine buildings, at the Cross; and a third was found at the site of the New Prison. Now all these ancient canoes were covered by sand and gravel, brought down by the river, in whose waters they had sunk. How many centuries have elapsed since they had so sunk it would be very difficult to determine, and if any of the great steamships for which our river is so justly celebrated have ever sunk, or will do so, they will furnish to the geologist, at some future ages of the world, a curious illustration of the progress of mankind. ("Hear, hear," and applause.) Having, then, arrived at the clear conviction that the stratified rocks of the earth have been all formed in the same way, by deposit from water, you will see at once that the first most obvious indication of their relative antiquity is simply their overlying or underlying each other. The stratum of sand in which the canoe was found, was more ancient than all the other strata which lay above it; the most recent deposit of the river being, of course, always the uppermost. This, then, is the first groundwork of classification in geology; and wherever it can be applied, it is the most direct and conclusive evidence of the relative age of strata. But we must remember that, in the very nature of things, we cannot expect in all cases to have that evidence to go by. The sea or the river which deposited a layer at one place deposited nothing at another place, because that other place was not at the time subject to the flow of its waters. All those portions of the earth which formed dry land during each geological period received, of course, no deposit from the sea of that period; and as there may be, and are, such portions of the earth which are not only dry land now, but have been dry land during many successive epochs, we cannot expect to find upon them any overlying strata. We cannot therefore judge of their own age by the indication of what lies above. Here, then, lies one great value of the discovery of Smith, that each stratum, or set of strata, among all the water-rocks, is characterised by its own peculiar fossils so that, by these fossils, each set of strata can be recognised, although found entirely separate from others with which it is elsewhere associated. Of course this discovery was itself first founded on the direct evidence of overlying or underlying position. Thus, for example, on the east coast of England—and I may add, also, in some spots of the north-east coast of Scotland—a series of sandstone beds, generally of a creamy or whitish colour, are seen to lie over another set of strata composed of mud and clays. The sandstones got the name of Oolite, and the clays were called "Lias."

Each have their own peculiar fossils; and in the lower of these strata they are very peculiar indeed. Now, when these last rocks are found elsewhere containing the same fossils, although there may not be actually present any overlying sandstones, we know that the rocks containing them are older than the Oolite, and that the Oolite, if it had existed at all at that spot, would have been found above, because it is the product of a later sea. In like manner, on the south coast of the Isle of Wight, whose rocks present one of the finest natural sections in Britain, the chalk hills are seen to be supported below by a great series of sands and sandstones; and, again, to bear upon their own backs another great series of strata, chiefly of clay and lime. All these have their peculiar fossils. Now, it is quite common to find all these strata separate from each other—the sands without any chalk upon their top—the clays and limestones without any chalk below—and the chalk dissociated from both. Moreover you can't be sure of recognising them merely by sight. Mineral aspect changes constantly. "The Old Red Sandstone" may not be sandstone at all. His Grace then alluded to certain mountains on the west coast of Rossshire and Sutherlandshire, which were thought by Mr. Hugh Miller to be Old Red Sandstone, and which, though certainly very old and certainly all sandstone, had been, during the last year, discovered by Mr. Peach, a person of great merit, not to belong to the Old Red Sandstone classification at all. A stratum of limestone had been discovered containing fossils belonging to the Siluriau rocks. His Grace then pointed out on a table prepared by Professor Rogers the various classifications of strata, and remarked that by means of the fossils we can always identify these separate strata; and, though found alone, we know their relative age, because at some particular place we have found their relative position. Proceeding, then, on this principle of classification, the whole stratified or water-rocks of the world have been found to range themselves in a definite order, or

above them. You will have no difficulty in understanding how this should be the case, if you have mastered the leading idea that, as all the stratified rocks have been laid down by water, and as there were probably always large portions of the earth above water, we cannot expect to find upon those parts deposits to which they were never subject. And, then, there is another reason why many strata should be wanting, even where they were once existing; and that is, that they have subsequently been washed away. We have the clearest evidence of this removal in numberless cases; one example of which I shall bring to your notice in the local description with which I shall conclude. This great series, then, of water-rocks which have been found to bear the relative position indicated in this section, have been classified into three great divisions. There has been some confusion in the naming of them, because certain terms which were applied before the true principle of classification had been discovered, had got such hold, that science has never got rid of them, and they now mix inconveniently with names founded on the true principle of division. But the simplest statement of the case is this—that with reference to order of time, the rocks have been divided into Primary, Secondary, and Tertiary; and that these correspond with another division founded on the difference in the fossils—the strata of old life, of middle life, and of recent life. The old-life strata include the lowest and oldest of all the strata which contain any remains of life, and terminate with certain rocks which lie above the coal-measures. The middle-life rocks extend from the top of these to the chalk inclusive; whilst the recent-life strata include all those which have been deposited since the period of the chalk, down to the latest changes before the commencement of the existing state of things. Hitherto I have spoken of the discovery of the different strata having each their peculiar fossils, only as a means of identifying them when found separate from each other, and thus of recognising their [illegible] place with reference to others and in reference to time. But for this purpose alone, any other peculiarity which was equally constant, would have been equally good. If, for example, it had been found that the strata lying under chalk were always of a certain colour or a certain texture, that colour or texture might have been sufficient to identify the position and age of those rocks when found alone. But the discovery in respect to fossils involved far more than this; it opened up an entirely new subject, new even to speculation, absolutely new to science. For, just think what fossils are, and what is involved in the discovery that each successive series of rocks have each their peculiar kinds. Fossils are the remains of life. They record, therefore, the form in which life has been embodied in the worlds which preceded our own. We are familiar with the idea of variety—almost endless variety—in the forms of life. It seems vast when we regard it, even in our own country; it seems still vaster when we regard it in connection with other countries, in many of which we should not recognise, perhaps, a single plant, or insect, or bird, or beast, identical with those which we know at home. When we see a new plant or a new animal, we know very well that it is only new to us; and we conclude, without doubt, that it has existed since the world began, although we have not been in a position to observe it. But there is

one thing of which we have no experience, and can hardly form even an idea—that is, the first introduction, or the first creation, of a new form of life. Yet this is the idea with which we must endeavour to familiarise our mind when we come to study fossils. For what do we mean when we say that each new series of strata in the history of the earth has a new or peculiar set of fossils? We mean that new plants and new animals have been formed from time to time, replacing others, which, in the same period, had died out and become extinct, each new series differing in greater or less degree from the series preceding—we mean that creative power has been exerted, not as we are apt to imagine, once for all, but continuously, perpetually—ever renewing its own work, with some diversity of pattern—some change of structure—some variety of purpose. And thus we find that, as in respect to the distribution of land and sea, our existing world is but one of the many aspects which the earth has assumed in the course of time; so in respect to all the living things by which it is inhabited—they do but represent the latest of the thousand forms in which life has been embodied in the world since its records began to be written in the rocks. Began! I have used the word instinctively, and rightly, in so far at least as it introduces us at once to the next great division of our subject. Began! Have we then found that which Dr. Hutton declared he could not find in geology, some "vestige of a beginning?" Hitherto we have been on ground which is not debateable. That the strata of the earth have been formed by water—that they can be arranged in the order of time—that they record the continual introduction of new remains. But plants and animals to replace others which became extinct—these are conclusions about which there is no doubt whatever; they are truths as firmly established as any in the whole range of the Physical Sciences. But with the further question which I have now suggested, we enter upon ground, every step of which is still contested. Without concealing my own opinion on the main points of controversy, my chief desire now is to state clearly what those points are, and what is



the case may be very simply stated. It is certain —no geologist denies it—that the lowest and oldest of our stratified rocks are entirely destitute of fossil remains; but many geologists argue against the conclusion that life did not exist when those strata were deposited, mainly upon two grounds. First, they say that these rocks, from the very fact of being the oldest in the world, have been subject more repeatedly than others to the various agencies of mineral change; and that it is a known effect of some of these to destroy and obliterate fossils, when we have every proof that they have existed in abundance. Secondly, it is sometimes said that we can never *be quite* sure of the non-existence of fossils until our search has been more complete than it has yet been; and rocks of much later date are also frequently found, though at a very great depth, equally destitute of fossils, although in their case it is known, from other examples, that contemporary life existed in the world. To the first argument it is replied, that many of the old strata, which are destitute of fossils, bear no evidence of any baking, or crystallisation, or any other mineral change which could obliterate fossils if they had ever existed; whilst to the second, I think it quite sufficient to reply, that our conclusions must be founded on such evidence as we have. These rocks have now been examined in every region of the globe, and though they contained all the usual varieties of original substance, lime, sand, and clay, the search has always led to the same negative result. Therefore, until farther search has actually led to the discovery of some fossils in those strata, we are entitled to assume that their non-existence indicates that life, if it existed at all, had not begun to be abundant in the world, or was restricted to low and perishable forms. I may mention that the rocks to which I now refer are largely represented in the west of Scotland. The rocks called gneiss and mica slate belong to them. The whole of that fine range of hills which faces the mouth of the Clyde, and forms so beautiful an outline from the quay of Greenock, is composed of mica slate; while gneiss is the foundation-rock of the country all along the north-western coast of Scotland. Any one of you who can find in any one of those strata any indication of a shell or other fossil, will have made an important discovery in geological science. He will have carried our knowledge of the history of life far back into the depth of time; and he will have rendered it far more doubtful than I think it is at present, whether we have or have not found in geology some trace of a beginning, at least in respect to the introduction of life. And then, as regards the second question—viz., whether, in the long series of specimens we possess, arranged in chronological order, we can detect any signs of progress, or of advance from a lower to a higher type of animal or vegetable life? The evidence on this point also can be understood by all. It is an unquestioned fact, that in the lowest and oldest rocks no animal remains have been discovered, except the remains of corals, shell-fish, and certain peculiar kinds of crab. It is equally admitted, that through a long series of strata which are the next *highest* and the next oldest, there is still an entire *absence* of warm-blooded animals, although the next order *above fish*—viz., reptiles—are beginning to appear. It is

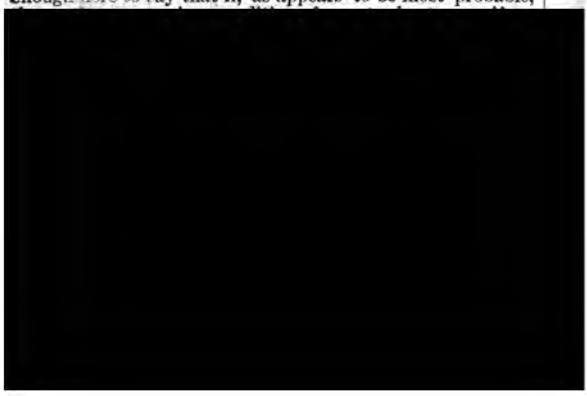
farther stated that the first warm-blooded animals which do appear, are of that low type which now exists principally in Australia—the pouched or marsupial animals—creatures which are known by keepers of wild animals to be the most stupid and indocile of all. Yet, farther, it is equally certain that as we arise through the succeeding strata, the higher warm-blooded animals rapidly increase, until, in the later ages of the earth, we are astonished by their abundance, and not less by their gigantic proportions. Last—not least in this catalogue of admitted facts—all geologists admit the telling fact that man was the last and latest of created beings—neither his remains nor his works being ever found in any but the most superficial deposits of our existing world. But perhaps some of you may be inclined to ask how, if this be a correct statement of undisputed facts, there can be any question at all that there has been progress in the order of creation, from a lower to a higher type? Well, one ground of objection is this—"Very true, it is said, the oldest rocks contain nothing but fish, shell-fish, and crabs. But what would you expect in strata which bear evidence of having been formed in deep sea water? You can't expect to find very often there the remains of land animals, though such may have existed abundantly at the time on some distant shore." To which again it is replied, "Recollect there are higher warm-blooded animals which live in the sea as well as on the land. These are whales, and grampuses of various kinds; and in latter strata, equally the produce of deep sea water, you do find remains of such sea animals in abundance, but none, not a vestige of them, in the oldest rocks." And again, in reply to the argument that we have not searched widely enough to establish the absolute non-existence of such remains, or of others of a high type, it is answered, as before, that we must be guided in our conclusions by such evidence as we have; and that until some discovery is made in the older rocks of warm-blooded animal life, we have a fair right to assume that

their number and variety, together with the total absence of higher animals, give us the strongest reason to believe that those offices of destruction which are now performed by warm-blooded and more highly organized beasts of prey, were in those ages of the world assigned to those monstrous lizards and crocodiles; and I own that I regard the universally admitted fact that the creation of man was the last and latest work, as one which [illegible]nosts leads us to expect as probable an analogous rule in the preceding history of the world. You will readily understand the interest which this question gives to every new discovery of fossils which casts any light upon it, or affords any corroborative evidence upon one side of the controversy or the other. Within a very short time—during the course of the last year—one discovery has been made in the south of England which carries down the existence of warm-blooded quadrupeds lower further back into time than they had before been known to exist. It does not appear to me, however, that the discovery affects the balance of evidence one way or another; for it turns out, on examination, that all the little quadrupeds which have been brought to light are of the same low Marsupial class which had been already found lower than any other in the strata. I come now to the third great question—by far the most interesting, but by far also the darkest—whether we can trace, in this history of life, any sort of indication of the employment of secondary causes in the introduction of new plants and animals. It is impossible that this question should not sometimes present itself to our minds when we contemplate the amazing fact, that creation has been not the special act of some special time, but a long series of acts constantly repeated and renewed. What should we have seen had we been present at the time and on the spot where some new form of life—let it be the least and lowest—came fresh from the hands of God? Should we have seen, for example, some existing shell become suddenly obedient to a new law of growth, and spread out in patterns which had been unknown before; or should we have seen the inorganic elements of which all animal frames consist, gather themselves visibly together, and be moulded before us in some new form of life? The wonder of the question comes more home to us when we put it in reference to some of the higher and more prominent types of animal life: the monstrous river-horse, the huge and sagacious elephant, or the various races from which our domestic animals have been derived. In regard to all of them we can see backwards to a time when none of them existed, and a time comparatively recent when they began to be. What idea can we form of the method of such a work? Is it possible that, by the suspension of the more ordinary laws of increase or by the disclosure of a higher law hitherto concealed, some pre-existing animal should become the progenitor of a race wholly unlike itself; and if we had been then living on the earth, should we have seen nothing but an apparently monstrous birth: or should we have seen suddenly fashioned from the dust, in complete stature, some creature endowed with new powers, and destined for new enjoyments? To these questions, however eagerly we may ask them, *science* hitherto has yielded no reply whatever. Such *evidence as it* affords is abundantly sufficient to negative that

theoretical solution which was attempted a few years ago in the famous doctrine of development. There is no appearance whatever of one animal having grown into another. Each new form appears perfect and complete, continuing identical until it disappears for ever. There are indeed links such as exist now between contemporary animals such as connect the lion with the pole-cat, or the eagle with the vulture. But there is no trace in nature of one having been derived by gradual passage from the other, or that any animal ever underwent any essential modification of its structure. We leave, then, this problem as we found it; rendering it highly probable, that of the mode and manner of creation we shall always remain in ignorance. One discovery, indeed, has arisen out of the more refined examination of animal forms, which is very wonderful, very mysterious, and in one sense may be said to indicate a law which has been followed in the exercise of creative power. It has been clearly established by the researches of Professor Owen, that in respect to one great department of the animal kingdom—I mean that great class called the vertebrata, or animals the most essential element of whose skeleton is a back bone, divided into segments called vertebræ—it has been proved, I say, with reference to these, that the special adaptation of new animals for special purposes and special spheres of life, has been so pursued as to be consistent with adherence to one type or pattern of organic structure; so that all the essential parts of that structure have been more or less retained, although modified (as we can form no idea), to suit the particular powers, habits, and enjoyments of each new form of life. Professor Owen illustrates this doctrine of comparative anatomy by referring to three different animals in the existing world, as widely separate apparently as any three that could be selected for the purpose: the mole which burrows in the earth—the bat which flies in the air—the whale which swims in the sea. Well, if we compare the two fore-

of force... logists now, however, are agreed in requiring suc... of time as baffle the imagination to conceive, and may ... with the similar demands which astronomy ... our conceptions in regard to space. Still, the que... ins, Have those vast periods of time been marked ... g more than a mere heaping-up, or accumulati... ical results? Has there not been a spending of ... an exhaustion of force—a passage from periods ... umult and preparation, to others of comparativ... and rest? There are three great sources of evi... which our arguments on this question must ... drawn: First, there is the position in which the ro... v seen, with reference to the mechanical forces ... hat position is an index and a measure. Second ... re the changes, whether sudden or gradual, which ... place in the animals and vegetation of the world. ... dly, there are arguments somewhat more hypoth... having, nevertheless, very strong foundations in ... nd analogy, derived from the probable—perhaps ... be said the necessary—condition of our globe ... tary body. I cannot now, of course, give even a ... of all the arguments on each of these heads ... great question has called forth in support of diffe... usions. My own conviction undoubtedly is, that ... ut the long ages of geology before the human ... e earth was subject to agencies of change such as ... r been exerted in any similar degree since man w... it is very true that these agencies, or others of a s... ure, are still giving evidence of their existence ... power;—it is very true that within the memor... ney have produced, and are even now producing ... which, though small and slow, would produce, at the ... pound interest of some million years, vast aggreg... We know of forests where our rude forefathers ... he wild ox and the deer, which are now covered ... and buried deep in the sands which ocean is ever ... n its spoils; we know of cataracts of melted stone, ... h from internal reservoirs of fire, destroying one ... n, and preparing new surfaces for another; we kn... ings and convulsions of the earth, which only s... er they have added to the height of mount... owered whole territories under the level of the ..., more, we know of a whole country in our ... ision of the globe—a considerable part of Eu... ch, as if by some mighty and unknown machin... slowly, steadily, imperceptibly being lifted ... t every century sees the tide mark a lower and lo... on its rising rocks. Still, no amount of change... these will account for all the phenomena which ... r in geology. In those Austrian and Bavarian ... which I have before referred, I could not help th... evidence singularly distinct. Time—enormous, ... le in its duration—is indeed required for the accumu... materials—for their consolidation—for the elevati... mass of strata. All these operations may have be... and gradual. But there must have come a *time* w... train or pressure was too tremendous for the *materi*... bear, and when, falling in and breaking up *they* w... and riven like the floes of arctic ice.

their surfaces are torn and broken, and we pass through the chasms they have left, seeing on either hand, widely separated from each other, strata which must have been once continuous, but are resting now in opposing slopes, which may be traced from the bottom of the valleys to the levels of eternal snow. Then there are other regions of the globe —our own Western Highlands among the number— where the position of the strata can only be accounted for by supposing that in whole districts they have suddenly fallen inwards, splashing up between the leaves of their deposit the melted granites which lay below. It may be that forces capable of producing similar effects are slumbering still; but assuredly they have never been called into similar exertion since the birth of man. In regard to the changes of animal and vegetable life, it is, I think, fair to admit that the progress of discovery has tended to fill up gaps, and to show that the passage from one set of inhabitants to another was more slow and gradual than at first it may have appeared to be. This, however, does not materially affect the question; because the most violent changes on the surface of the globe have probably affected only small portions of that surface at a time, and might have very small effect on the destruction of races more widely distributed. There are still, however, some great chasms to be filled— one in particular between the deposition of the chalk and the earliest succeeding strata. How long that period may have been we know not; but it seems pretty clearly ascertained that it was one through which no living thing survived. When creation again appears, it is with a face entirely new. It would be difficult to suppose that this period, in respect to mere lapse of time, represents a greater transition than any other in geology. The inference therefore is, that it was a period of greater physical change. As regards the arguments derived from the early condition of our globe as a planetary body, it may be enough here to say that if, as appears to be most probable,

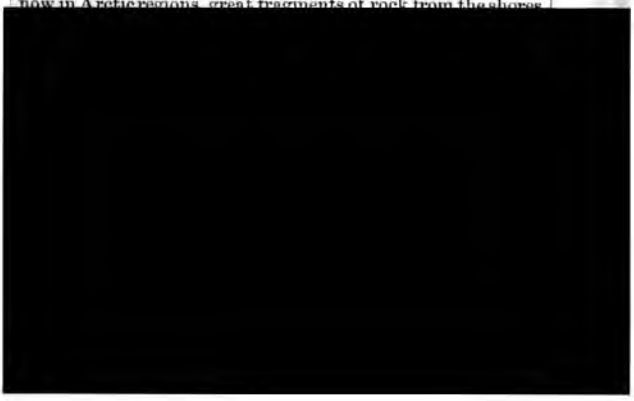


feature in that history receives no explanation from the hypothesis of a constantly decreasing heat. Down to a certain period, and that almost the last and latest, all the facts, so far as we yet know them, are at least consistent with that supposition. There seems to be no doubt whatever that the animals and the plants of former worlds indicate that a warmer temperature prevailed over the globe than prevails at present. Even the seaweeds of the older rocks are now represented by genera peculiar to southern seas. No vegetation now known in the hottest regions of the earth—not even that which, on the eastern coasts of tropical America, is the very paradise of botanical wonders—equals or approaches the wonderful vegetation from which the coal measures have been derived. Yet that vegetation flourished, not only in this our own latitude, now so temperate, but also in arctic regions now covered with perpetual ice and snow. And after that, all through the secondary ages, both the animal and vegetable remains are allied more or less distinctly to those families which prevail in the warmer latitudes of the world. Again, when we come down to the beginning of the Tertiary ages, we find, in a deposit at the mouth of the Thames, fossils in vast abundance, very similar to those which Indian floods are now accumulating in the delta of the Ganges. In the succeeding strata, the plants and animals assume more and more closely the character of existing forms, indicating a steady approximation to those conditions of climate which obtain in the existing world. But, strange to say, between the latest of these tertiary strata and man's creation, there seems to have intervened, at least all over the Northern hemisphere, a period of infinitely greater cold than that to which we are now exposed, As compared with that penultimate period in the past history of the globe, its climate has been changing, not from a greater to a less degree of heat, but, contrariwise, it has been getting warmer. So far as this singular fact bears upon the main question, it seems to favour the arguments of those who maintain that the changes of climate throughout the whole history of geology have arisen from geographical rather than from planetary causes—from changes in the distribution of land and sea, rather than from any which are connected with the internal heat of the globe. Certain it is that the same evidence which proves conclusively that the very last change recorded in geology has been one from almost arctic cold to that temperate climate which we now enjoy, proves as clearly that the change has been accompanied by changes as remarkable in physical geography. These changes, however, so far as we know their nature, do not appear to have been such as would naturally tend to raise temperature. The height of mountains above the sea, and extent of continent beyond the influence of the sea, are well-known causes of colder climates. But in that very cold period of which I have spoken our mountains appear to have been very much lower than they are now; or, to use a graphic expression of Hugh Miller, the whole country "sat low in the water." Yet its heights seem to have been crowned by glaciers—floating icebergs grated along their sides—*and shells*, for which you must now go to the shores of the

Frozen Sea, lived in multitudes in our own valley of the Clyde. This fact was first brought to light by my friend Mr. Smith, of Jordanhill, whose researches, both literary and scientific, must be known to many of you. The shells of an arctic climate, which he was the first to discover, have now been found at very various elevations, up to feet above the level of the sea. Surely it is one of the most wonderful facts revealed by geological science, that, after the whole cycle of former changes had been completed—after the surface of the earth had assumed, for the most part, its existing configuration, there has been time for a slow and steady upheaval of its general level to the extent which those shells indicate, before it was sufficiently prepared for the dwelling-place of men. Besides the testimony of shells—the most direct and conclusive of all—there is another evidence. Many of you may have observed all over the West and Northern Highlands, as also in the lake country of Cumberland and Westmoreland, enormous blocks or boulders of stone, very often perched upon the very tops of the hills. It is impossible, when one's attention is directed to the singular situation of these blocks, not to wonder how they could possibly have been so placed. Wordsworth refers to, and has well described them in the following lines :—

" As a huge stone is sometimes seen to lie
Couched on the bald top of an eminence,
Wonder to all that do the same espy,
By what means it could hither come, and whence,
So that it seems a thing endued with sense,
Like a sea-beast crawled forth, which on a shelf
Of rock or sand reposeth, there to sun itself."

It is a curious example of the coincidence of true poetic imagination with the truths of nature, even when these truths may not themselves be known, that the illustration here chosen by Wordsworth makes a very close approximation to the actual explanation now given by geology. The hill-tops on which these boulders lie must have been shoals or shelves of rock comparatively near the surface of the glacial sea, and the floating icebergs which then carried, as they do now in Arctic regions, great fragments of rock from the shores



Giants' Causeway. The important point in this discovery was this:—Previous to the discovery of these leaves, no portion of the great series of tertiary rocks had been found in Scotland. It appeared that forest vegetation had existed on the top of this basaltic rock, and had been overflowed by volcanic mud bursting through a bed of chalk. Now, chalk was not found in Scotland, but here there were flints, which geologists well knew were peculiar to the chalk formation, and which must have been left there after the chalk had been comminuted and carried away. It was thus plain that on the bleak shores of Mull, and the Western Highlands, there was once a forest vegetation to which only tropical regions now afforded a parallel. This vegetation was at different times overflowed by volcanic ashes, as was evident from the existence of three separate beds of mud and leaves, lying between strata which had once been lava, and a mass of basalt over all. And, finally, there was proof that such had been the subsequent changes which had come over this globe of ours, that the chalk formation had disappeared, and left no traces behind, except in the chalk flints. His Grace concluded as follows:—I have no intention of entering upon the religious difficulties which the progress of geological discoveries has been supposed to raise. A large number of them have been overcome; that is to say, they have been seen to be no real difficulties at all, but to have depended, as in the case of astronomy, on the erroneous principles of interpretation which had been applied to the words of Scripture. Such difficulties as remain will, in all probability, receive the same solution; and thus the progress of truth in one department contributes to its progress in another, for surely no unimportant advantage is attained when new light is cast on the conditions under which the literal terms of Scripture narrative or parable are to be understood. It may be well, however, in closing this lecture, to say a few words on the general result of geological science as a whole, and the prevailing impressions which it leaves upon the mind. And, first, looking outwards, as it were, the first idea which it presents, almost with overpowering force, is *Time*—illimitable lapse of Time. Years cease to measure it; cycles of ages appear too small a unit with which to number its duration. When we think of it we may repeat, with some nearer approach to an understanding of their meaning, the words of David—"In thy sight a thousand years are as yesterday when it is passed, and as a watch in the night." (Applause.) The next idea which is brought forcibly before our mind is this—that, during that enormous lapse of time, a progressive series of events has been directed to a definite and foreseen result. Here, again, old and familiar words seem to bear a new sense—to be deeper and truer than we ever knew before:—"The sea is His; and He made it; and His hands have PREPARED the dry land." What a long preparation that has been! How many worlds succeeding worlds have been required to produce our existing earth, with its variety of surface and of climate—its stores of coal, and lime, and iron—the indispensable materials of human industry and wealth! And *then, that* wonderful history of animal life, in which we see *it built up from* low beginnings, through the dreadful dragons

and monsters of the middle ages of geology to the higher race which now minister to the wants of man! Of all this, no other word than the word "Prepare" gives the explanation or the meaning; for it must be always remembered that what are called natural laws are not really explanatory. They define the rules according to which certain effects are produced; but they do not explain to us either the how or the why. Yet these are the ultimate questions which the human mind is ever asking, and without an answer to which nothing can be fully understood. Because it is in the answer to these questions that we can alone recognise the creating and directing will. Causes are not reasons; but the reason of a thing is its only real explanation to a reasoning mind; there is nothing intelligible except intelligence. (Applause.) And now looking inwards at ourselves in the light of this science, the first idea that must strike us is that which is first by the mere force of contrast, the almost infinite smallness of our own term of life. "Behold Thou hast made our days as an handbreath, and our age is as nothing before Thee." But then comes a contrast of another kind—a contrast between our littleness in one aspect and our greatness in another. Our desire to know, and our capacities of knowledge, how large and wide they are as compared with our power of finding out! We can discover, and we have discovered much—we seem to see what passed ages before we were born, or our race began. But the deepest and highest truths which we long to know are inaccessible to our researches. At moments we may be beguiled with the hope that we are on the point of seeing something of the mysteries of creation; but they recede as we advance. The Creator eludes our search. This is as true now as it was in the days of Job—"Behold, I go forward, but He is not there; and backward, but I cannot perceive him: on the left hand where he doth work, but I cannot behold Him: He hideth himself on the right hand that I cannot see Him." What then is the last

and feeling, Tennyson's "In Memoriam." Speaking of knowledge or science, he says :—

> Half-grown as yet, a child, and vain—
> She cannot fight the fear of Death.
> What is she, cut from love and faith,
> But some wild Pallas from the brain
>
> Of Demons? fiery hot, to burst
> All barriers in her onward race
> For power. Let her know her place;
> She is the second, not the first.
>
> A higher hand make her mild,
> If all be not in vain; and guide
> Her footsteps, moving side by side
> With Wisdom, like the younger child!

His Grace concluded amidst long-continued and hearty applause.

Jan 4 26 1883
Daily Review

THE GOLD-BEARING ROCKS OF SCOTLAND.

It was a common opinion among scientific men some twenty or thirty years ago, that the crystalline rocks of Scotland, especially those of the Highlands, which were believed to be of the same geological age as the central Alps of Switzerland, like them abounded more in gems and crystals than in metals. But a new belief is now rapidly spreading, that the truly primary or oldest class of rocks with us are confined to a very small district in the north-west of Sutherlandshire, and to one or two points in the adjoining Outer Hebrides; and that the great map of the Highlands, including our highest mountains in Ross, Inverness, Perth, and Argyllshires, are of much more recent origin, and belong to the Silurian system—those rocks, viz., in which the first dawning of organised life, in both vegetables and animals, makes its appearance. The patient researches of Mr Peach, of Thurso, have demonstrated that there are real organisms (orthoceratites, &c.) in some of the very hard crystalline quartz rocks and limestones of Erriboll and other parts of Sutherland, which old Dr Macculloch either scouted as such, or thought them but freaks of crystallisation; and upon the foundation of these discoveries, the Direc-

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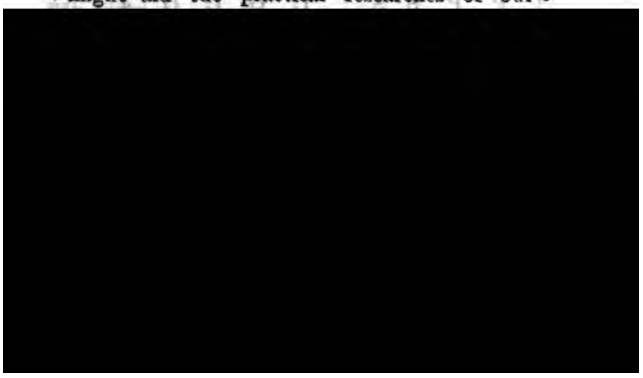
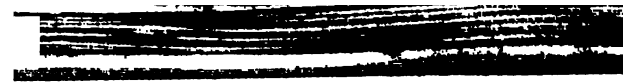
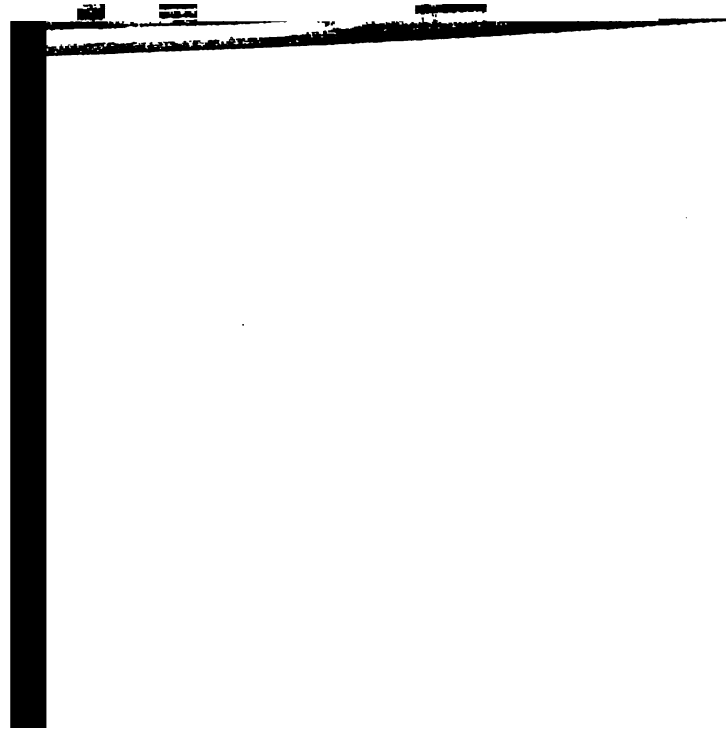
to have been ejected from volcanoes, and to have fallen on a wet surface or shallow sea, whence it is found generally in detached molten nodules, or grains and nuggets, rather than in connected veins or large masses. It is peculiarly characteristic of quartz rock mountains, and is now discovered not only embedded in the rock, but so minutely disseminated through it as to have given rise to the quartz crushing mills, and to the belief that the common golden colour of the rock is caused by microscopic auriferous scales, requiring chemical agents to separate and collect them. These later discoveries have induced a search for the precious metal farther away from the alluvial and loose gravel beds in which it was at first found, and more into the bowels of the rocks themselves; and hence, as all its modes of distribution have not yet been likely traced out, gold will probably be discovered in many localities not hitherto dreamt of as containing any trace of it.

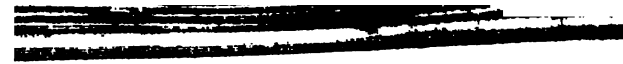
At various periods, and in several different places, gold has been found in Scotland. It is known that some of our early Scottish monarchs used native gold to a large extent, if not wholly, in their coinages; and perhaps our antiquaries may yet be able to demonstrate that the ancient bars of gold used for money, and the golden trinkets and ornaments of the olden Druidical priests and chiefs were formed more from the auriferous products of the country than is generally supposed. The most important locality for Scottish gold has always been the district of the Lead Hills, south of the Lothians; where, certainly, if anywhere, the electro-magnetic agencies which accompanied the formation of the metals occurred in the greatest variety and intensity of any part of this kingdom. The slaty rocks of that district have now been proved to be of Silurian age, and to bear a close resemblance to the auriferous metamorphic slates of Otago and of the other rocks in which gold is now being so extensively found in New Zealand. Dr Lindsay of Perth, at the late meeting (October 1862) of the British Association at Cambridge, referred to these resemblances, in two papers which he read on the gold-fields of Auckland and Otago,

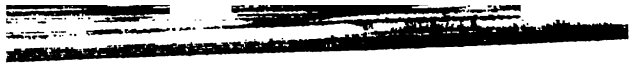
which he had examined; and we understand that it is the doctor's opinion that these so entirely agree, both in mineral and stratigraphical character, with the Scottish rocks, that gold is likely to be more widely distributed in Scotland than is at present supposed. The main fact to be kept in view is that all the world over the most profitable gold beds are connected with *Silurian* rocks, although it is also pretty widely disseminated in other formations. The peculiarly volcanic-looking detached quartz rock deposits of the Durnhill of Portsoy, the Bein Hills of Cullen and Huntly, the singular sharp peaks of quartz in the Paps and Scarabeans of Caithness and Jura, as well as those in Sutherlandshire, all deserve further examination. We would venture to suggest that our local geologists should unite and communicate with one another on this interesting inquiry. Even if it should not be found that the gold deposits of Scotland could be *profitably* worked (and we should be sorry to recommend a reckless and mere mercenary search); yet there can be no doubt that the study of the relations in which the gold occurs among the rocks with which it is associated in this country, as well as the ascertaining of those in which it is *not* to be found, would be of great interest, and might aid the practical researches of our

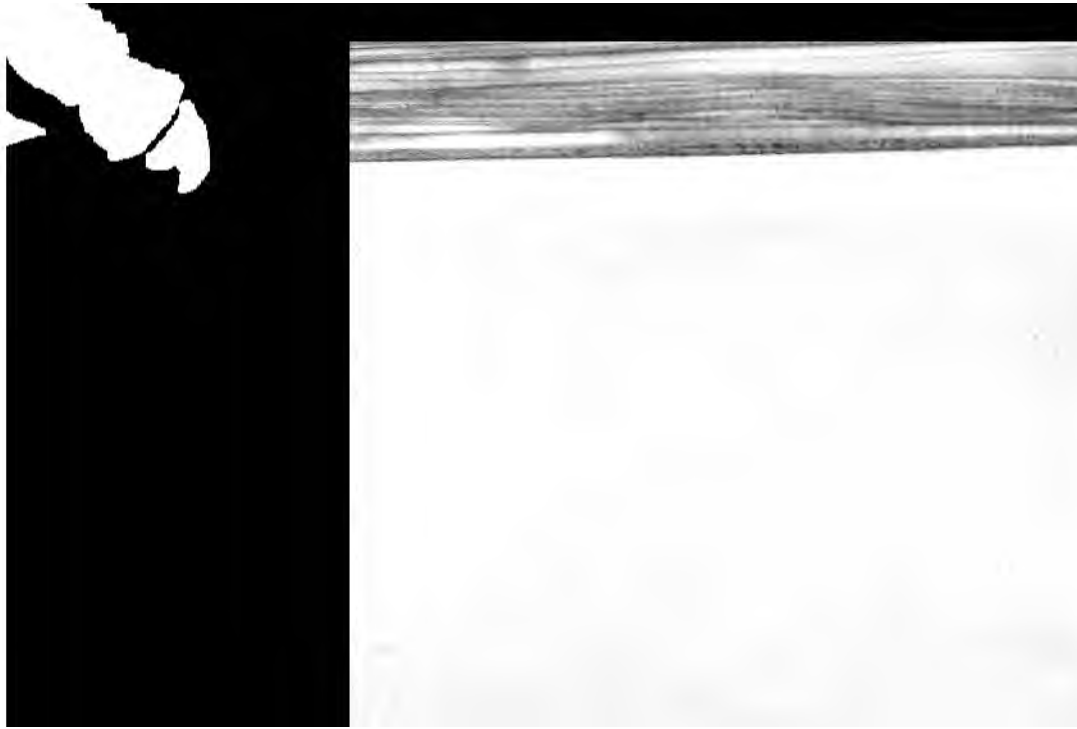


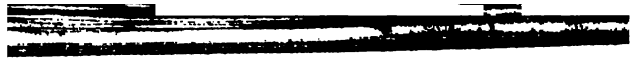


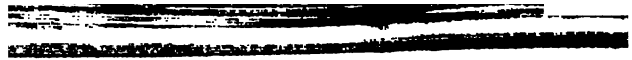


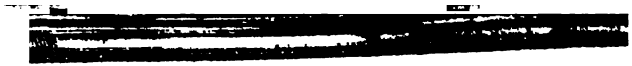


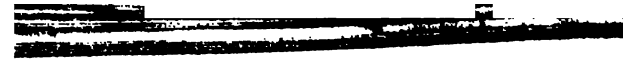


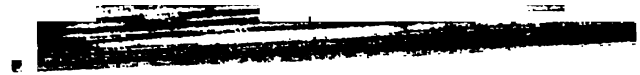












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